



# *Basic IMPRINT Workshop*



Approved for public release  
Distribution unlimited



# *IMPRINT Team*

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Mr. John Lockett  
jlockett@arl.army.mil  
410-278-5875

Ms. Jody Wojciechowski  
jqw@arl.army.mil  
410-278-8830

Ms. Celine Richer  
cricher@arl.army.mil  
410-278-5883

Ms. Charneta Samms  
csamms@arl.army.mil  
410-278-5877

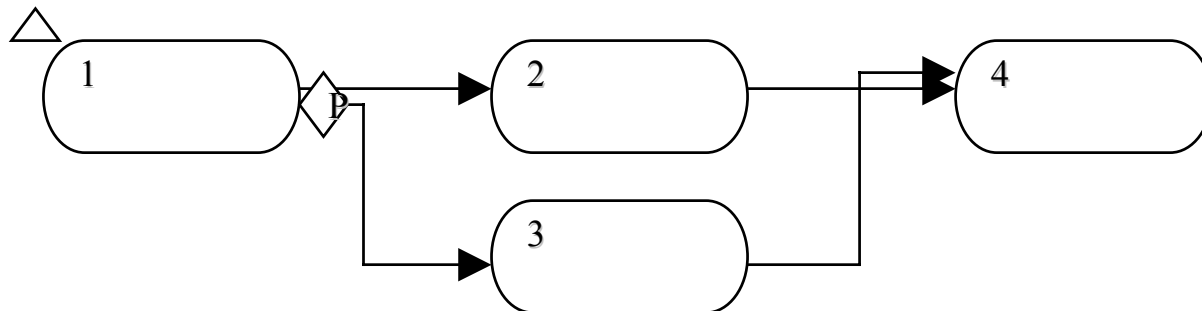
Ms. Diane Mitchell  
diane@arl.army.mil  
410-278-5878

Mr. Alan Dorney  
adorney@arl.army.mil  
410-278-5892

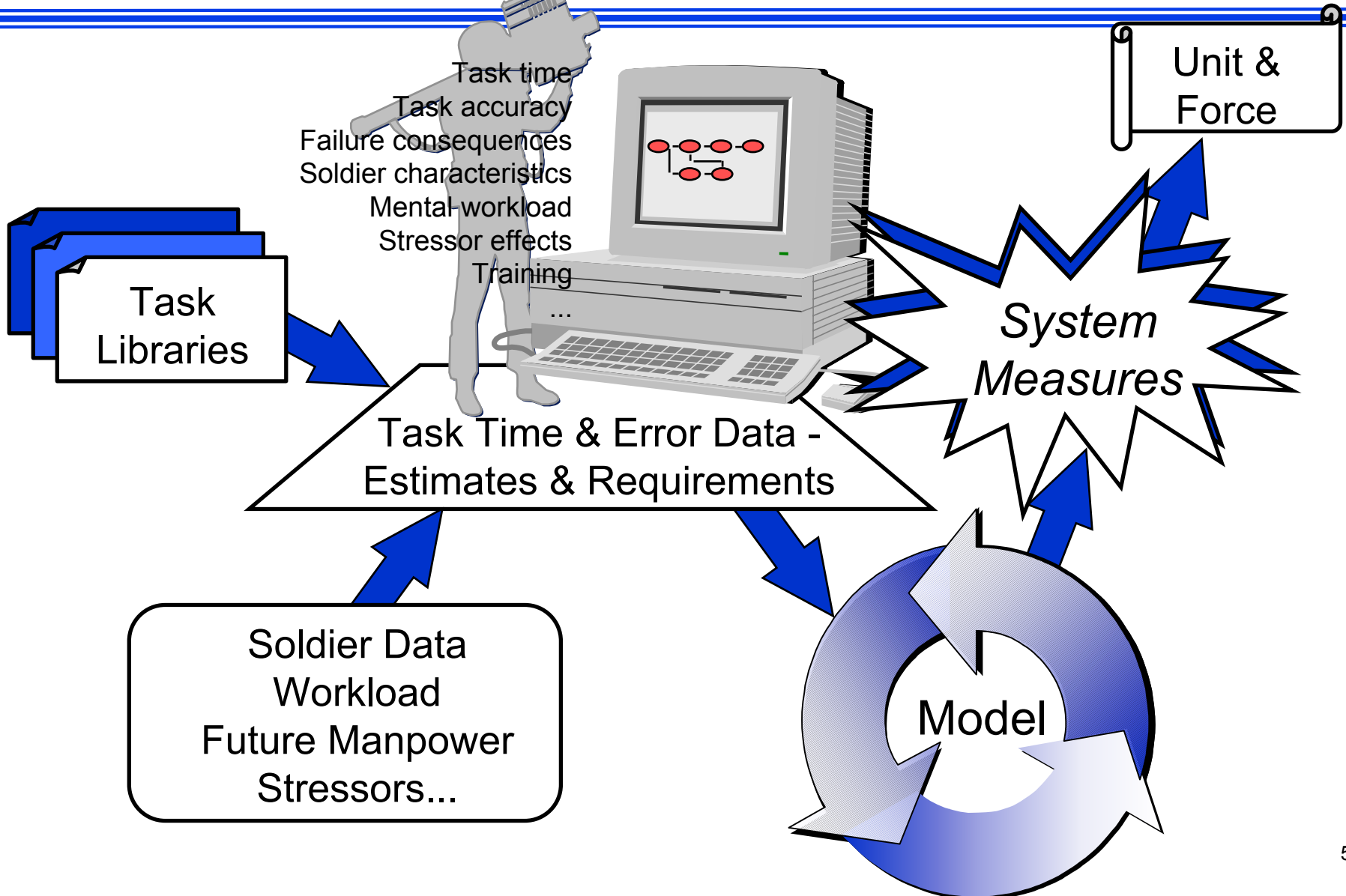
# *Introduction*

# What is *IMPRINT*?

- ◆ It is a ***tool***
- ◆ Army-developed soldier-system analysis ***tool***
- ◆ Improved Performance Research Integration ***Tool***



# IMPRINT Architecture





# *What Does IMPRINT Do?*

*It helps you...*

- ◆ Set realistic system requirements
- ◆ Identify future manpower & personnel constraints
- ◆ Evaluate operator & crew workload
- ◆ Test alternate system-crew function allocations
- ◆ Assess required maintenance manhours
- ◆ Assess performance under extreme conditions
- ◆ Examine performance as a function of personnel characteristics, training frequency & recency
- ◆ etc.

# How Does *IMPRINT* Do It?

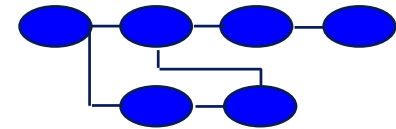
- ◆ Stochastic task network modeling

- Build your own mission model

time, accuracy, task type, failure...

- Parameterize maintenance model

MTTR, MOUBF, combat damage, rounds fired...



- ◆ Workload modeling: VACP & Advanced
- ◆ Performance shaping functions & stressors
- ◆ Manpower projection
- ◆ Access data libraries: System & soldier data
- ◆ Force-level roll-up



# *IMPRINT: Evolution & Revolution*

1970's

**Concept Paper**  
**~Air Force~**

**MPT data provided**  
**- Paper & pencil -**

**Navy HARDMAN**  
**(Hardware vs. Manpower)**

1980's

**Automated process**  
**- Mini-computer -**

**Army HARDMAN II**

**MPT link to performance**  
**- PC -**

**Army HARDMAN III**

1990's

**Integrated analysis environment**  
**- Windows -**

**IMPRINT &**  
**WinCrew**

2000+

**Goal Oriented Behaviors &**  
**HLA Compliance**

**IMPRINT 6**





# *IMPRINT Verification, Validation & Accreditation*

- ◆ Per AR 5-11, Army Model and Simulation Management Program
- ◆ Accreditation Board
  - ADCSPER, Chair & Members representing policy, users, testers, materiel developers, decision makers
- ◆ Effort completed 2QF 95 -
  - Define Mission, VACP, PTS
- ◆ IMPRINT is a tool for building models & includes embedded models!
- ◆ VV&A may be required for user-developed models

# *Extra Benefits of Doing V&V*

- ◆ It's a great way to debug software
- ◆ It drives you to document model assumptions and limits
- ◆ It goes hand in hand with configuration management
- ◆ It helps build toward model standards, data sharing, etc.
- ◆ It's a way to reduce system risk
- ◆ If you do it right in the beginning, the “savings” are realized throughout the life-cycle
- ◆ It helps you develop rapport with the customer
- ◆ It helps build credibility for human performance modeling across the board!





# Who Has IMPRINT?

◆ Army	107
◆ Navy	23
◆ Air Force	8
◆ Marine Corps	2
◆ Other Government	9
◆ Contractors	105
◆ University	18
◆ Foreign	1

*273 and growing !*



# IMPRINT Web Page



## IMPRINT

Improved Performance Research Integration Tool

Version 7 now available!

### *Links to other sites:*

[ARL Home Page](#)  
[Dept. of the Army](#)  
[WinCrew](#)  
[Micro Saint](#)

### **What is IMPRINT?**

IMPRINT is a Human Systems Integration (HSI) and Manpower versus Hardware Integration (MANPRINT) tool developed by the U.S. Army Research Laboratory, Human Research & Engineering Directorate. It is a dynamic, stochastic discrete event network modeling tool designed to help assess the interaction of soldier and system performance throughout the

<http://www.arl.army.mil/ARL-Directorates/HRED/imb/imprint/imprint7.htm>

# Development of Analysis

OR

D . O . A





# *What is a Model?*

Mr. Webster says:

**1. A small object, usually built to scale, that represents another, often larger object. 2. A preliminary pattern serving as the plan from which an item not yet constructed will be produced. 3. A tentative description of a theory or system that accounts for all of its known properties.**

Law and Kelton say:

**Mathematical and logical relationships that describe system behavior.**

Mr. R. Estell says:

**An abstraction of reality.**

# *Why Modeling?*

Many Variables



Concept System

Too Dangerous

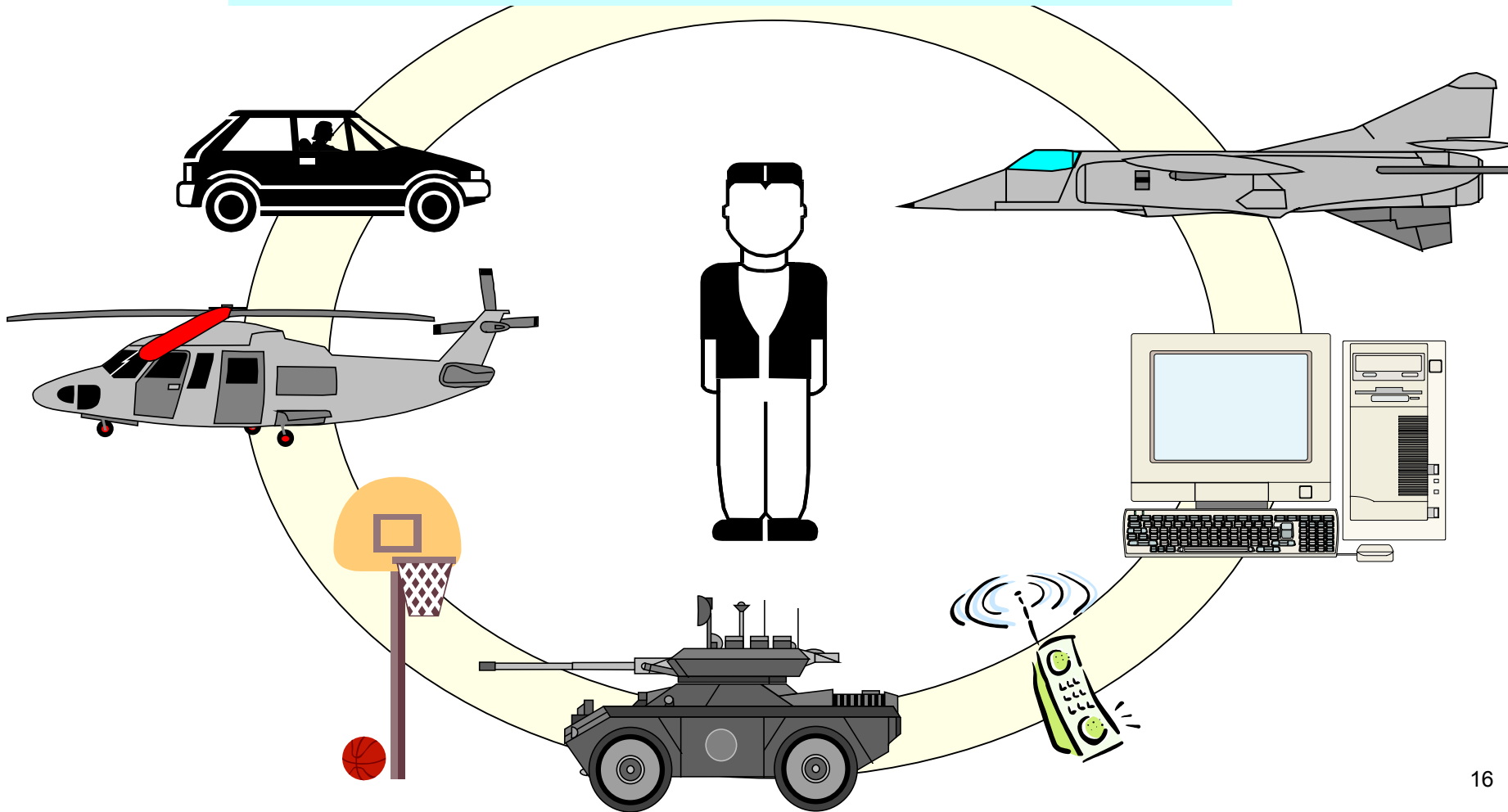


Field Study Not Feasible

**Model – Test – Model**

# Why Human Performance Modeling?

System Performance =  $f(\text{human performance})$





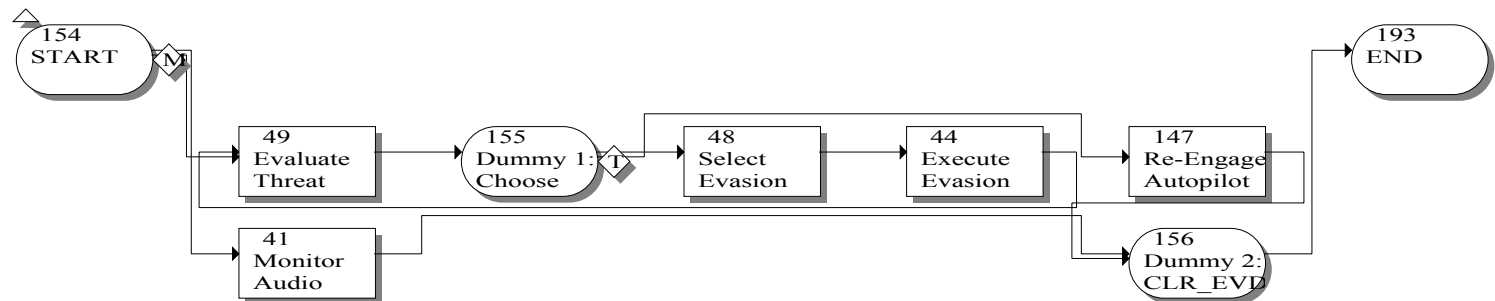
# Task Network Human Performance Modeling

## INPUTS

- Time and accuracy of each task
- Consequences of “poor” performance

Gathered from such sources as existing data, algorithms, and estimates from SMEs

## MODEL

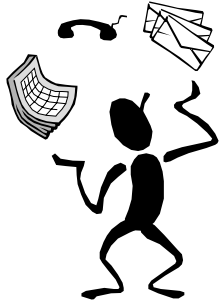


## OUTPUTS

Measures of effectiveness

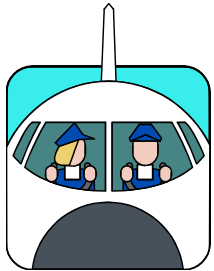
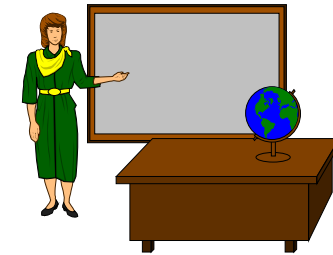
Not descriptive models, but predictive models

# *What Does Human Performance Modeling Tell Us?*



Is the human overloaded with tasks?

Will training improve human and system performance?



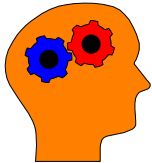
How to allocate tasks between human(s) and automation?

What are the performance tradeoffs with different system designs or levels of operator experience?

# Typical Measures



Task time and accuracy



Operator workload level



Number of operators  
required

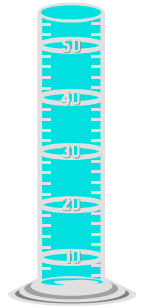
Impact on  
System  
Performance

# Challenges to Human Performance Modeling

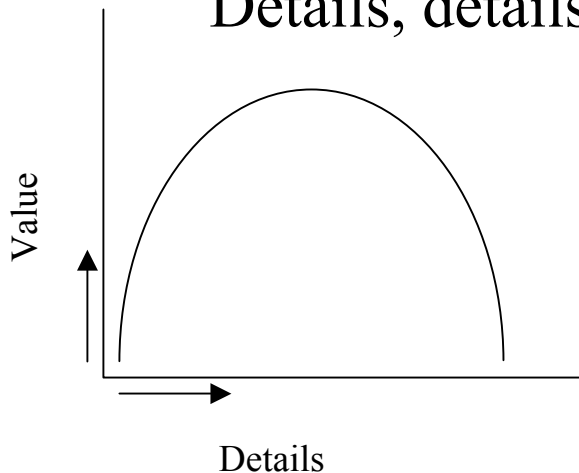
Clear questions



Appropriate measures



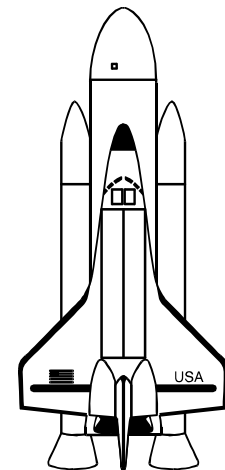
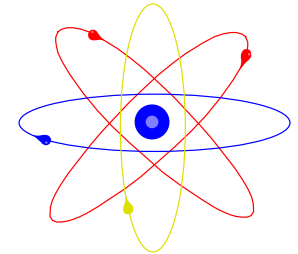
Details, details, details



Input data collection

# Scientific Method

- ◆ Determine the problem - What is your question? Observation!
- ◆ Make a hypothesis - What is your prediction?
- ◆ Test your hypothesis - What steps and measures are necessary? What tool?
- ◆ Analyze your results
- ◆ Draw conclusions



# *Loading the Software*



# *System Requirements*

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- ◆ Pentium
- ◆ 128 MB RAM – Minimum
- ◆ 75 MB disk space
- ◆ VGA
- ◆ Windows 98 or Windows NT/2000/XP
- ◆ Office for enhanced reporting & graphing

# *Installing IMPRINT*

- ◆ Installs from CD to hard drive
- ◆ Default directory: C:\imprint7 (cannot be installed over top a previous version)
- ◆ If previous version exist (version 5 or 6 only) then all analyses are converted first time IMPRINT is used.



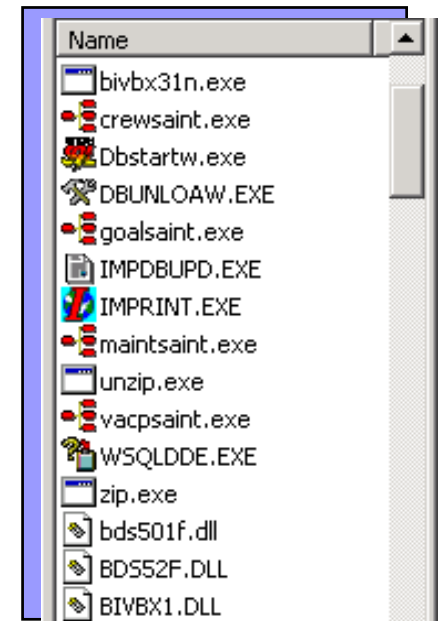
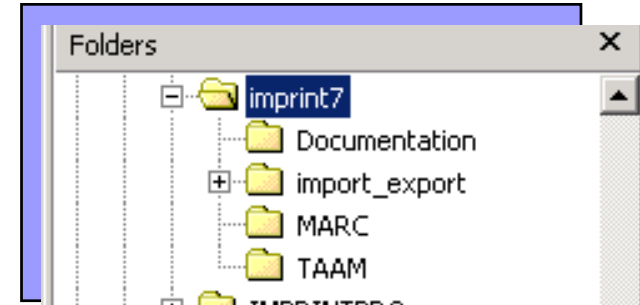


# *IMPRINT Basics*

# The IMPRINT Directory

## ◆ What's in it

- Executable files, & DLL files
- IMPRINT database files
  - » “library” files - stuff that “comes with” IMPRINT
  - » “user” files - your stuff
  - » “working” or “session” files -  
for the open analysis
- Report files - linked to an analysis
- Help files
- Documentation & Readme
  - » Analysis Guide & User's Guide



## ◆ What isn't: Your analysis by name!



# What Your Analysis Looks Like

When you open IMPRINT you will -

◆ Create a new analysis

- Starting from scratch
- Or using a library system

*Libraries are for reference or quick start  
But you are not required to use them!*

Create A New Analysis

Analysis Name:

Analysis Version:

Selected System:

Description:

Use Library Data

Ok

Cancel

Help

◆ Or open an existing one

Open Existing Analysis

Existing Analysis List:

Analysis Name	Analysis Version	Last Opened	Mission Area	System Type	System Name
Define Equipment	Workshop	10 / 24 / 2003 13:09:37.0			
RSV	Sep 11	9 / 18 / 2003 11:02:57.53			
Express Lane	1	8 / 21 / 2003 10:56:57.82			
APG-Workshop	Class	8 / 11 / 2003 09:02:48.56			
Common	Class	7 / 24 / 2003 10:18:08.54			
Scout FCS	25 June 03	7 / 23 / 2003 10:01:02.37	Combat Service S	Light Truck	M998 HMMWV
Combat analysis	2	6 / 25 / 2003 13:45:28.29			
MGS advanced	2	6 / 25 / 2003 13:30:26.03			
FCS Scout	1	6 / 24 / 2003 07:31:51.16	Combat Service S	Light Truck	M998 HMMWV
STRYKER	16 Sep 02	5 / 8 / 2003 08:59:06.33			
Starter Motor	1 May 03	5 / 7 / 2003 14:45:19.70			
Starter Replacement	07 May 03	5 / 7 / 2003 09:43:21.92			
Chatty Cashier	1	5 / 6 / 2003 14:01:14.60			

Analysis Description:

Ok

Cancel

Help



# The IMPRINT Library

Select Library System

Mission Area	System Type	System Name
Air Defense	Man-portable Air Defense System	STINGER
Air Defense	HIMAD	Patriot FP
Air Defense	Air Defense Mobile Gun	M163 VULC
Aviation	Utility Helicopter	UH-60A
Aviation	Scout Helicopter	OH-58D
Aviation	Cargo Helicopter	CH-47D
Aviation	Attack Helicopter	AH-64A
Close Combat Heavy	Tank	M1 ABRAMS
Close Combat Heavy	Cavalry Fighting Vehicle	M3 BRADLEY
Close Combat Light	Rifle	M16A1
Close Combat Light	Man-portable Indirect Fire Weapon	M252 81MM
Close Combat Light	Man-portable Anti-tank Weapon	DRAGON
Close Combat Light	Infantry Fighting Vehicle	M2 BRADLEY
Close Combat Light	Grenade Launcher	M203
Close Combat Light	Automatic Weapon	M249 SAW
Close Combat Light	Anti-tank Vehicle	M901 ITV
Combat Service Support	Light Truck	M998 HMMWV
Combat Service Support	Heavy Truck	M977 HEMTT
Fire Support	Towed Howitzer	M102 HOW
Fire Support	Self-propelled Howitzer	M109A2 HOW
Fire Support	Rocket Field Artillery System	MLRS
Fire Support	Medium Range Missile Artillery	LANCE

Ok Cancel Help

Embedded data include: task network, task times, workload, repair & failure times, soldier skill etc.

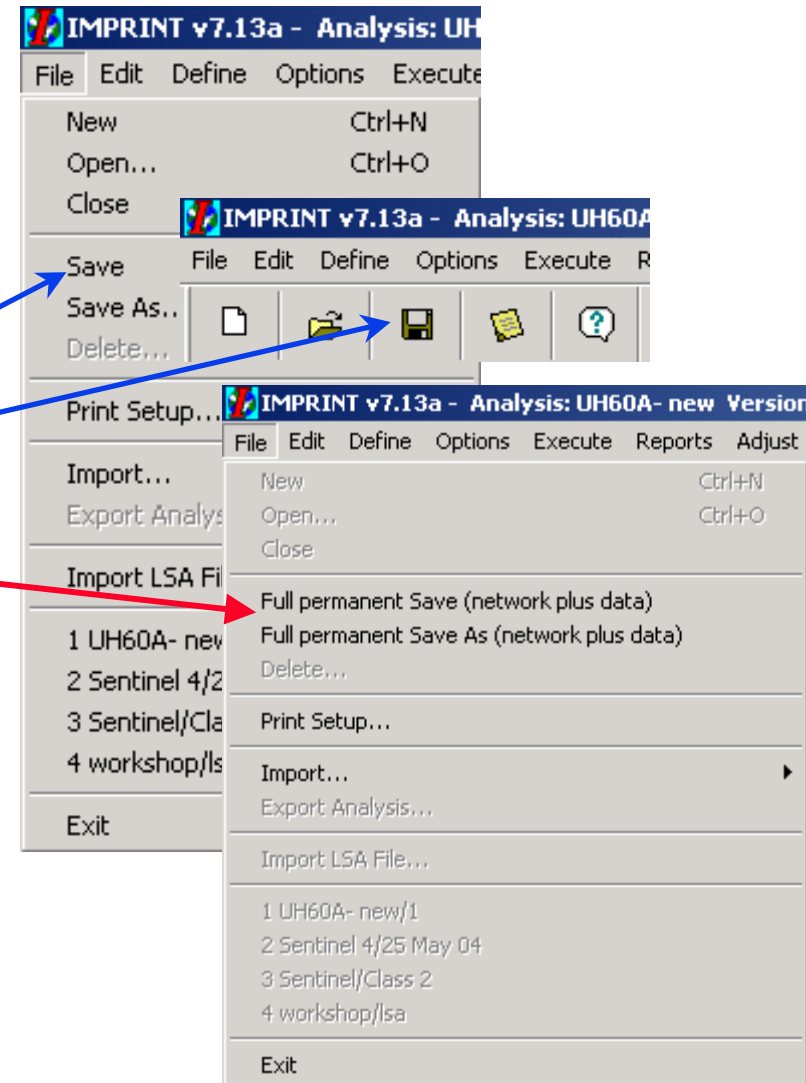


# *Navigating within IMPRINT*

- ◆ Windows “standards” (to the extent possible)
  - OK goes back one and saves
  - Cancel also goes back one & does not save
  - Other buttons advance
- ◆ Deeply embedded windows
  - Navigate from top > down
  - At embedded levels, also navigate sideways
- ◆ Multiple ways to access data
  - Lists, graphics, spreadsheets

# Saving Your Analysis

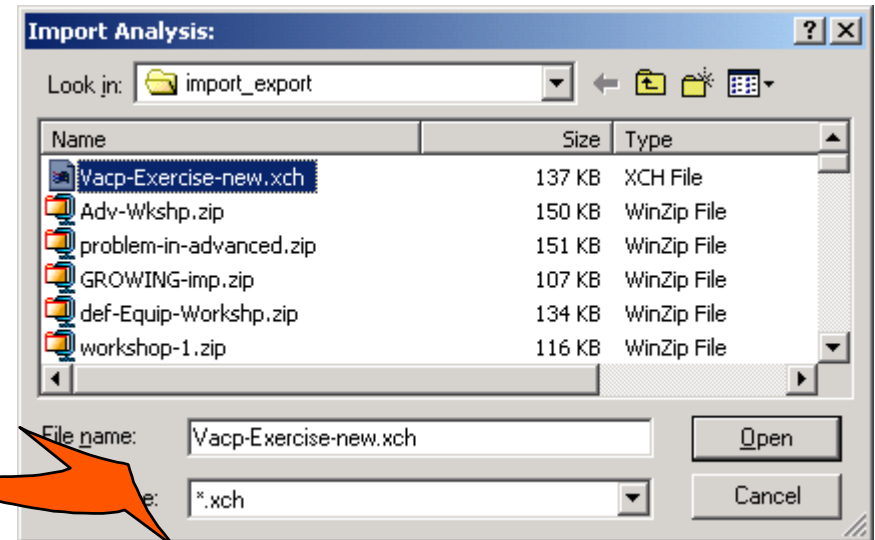
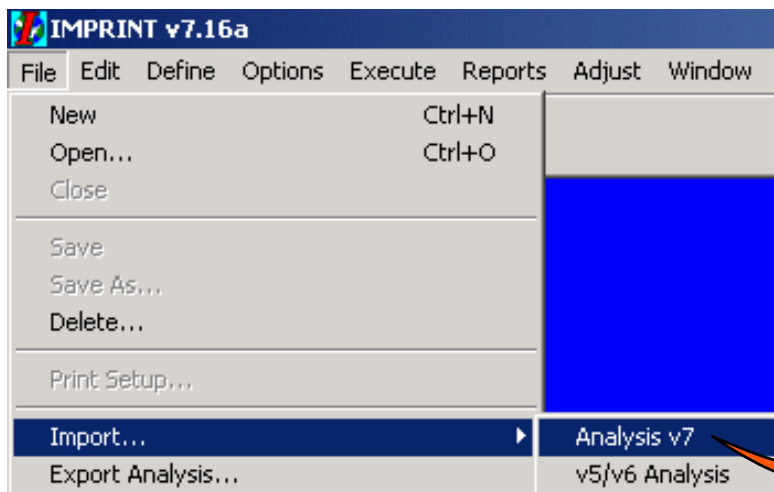
- ◆ Save early, save often\*  
\*from the top-most window
- ◆ Save again as you exit
- ◆ Saving your analysis
- ◆ Saving your network diagram & information
- ◆ When in doubt, save
- ◆ Reminders are legitimate!





# Sharing Your Analysis Using Import & Export

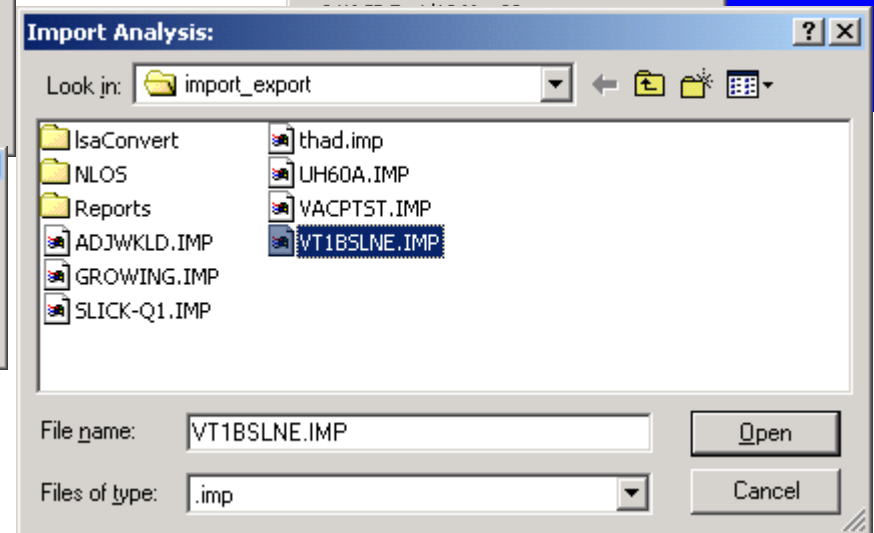
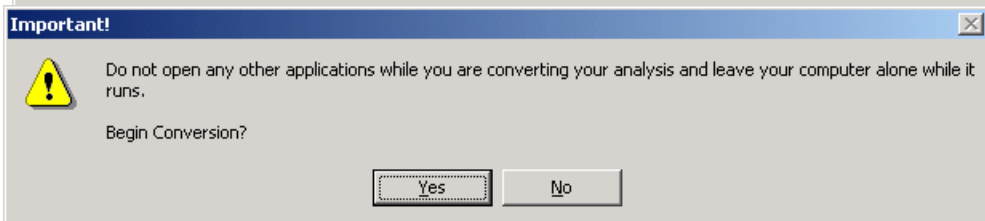
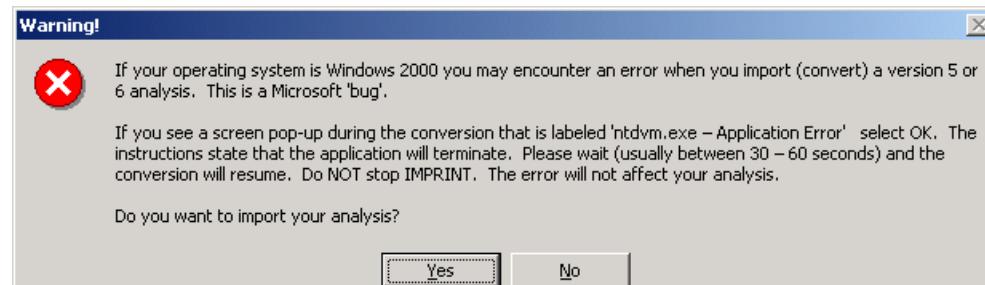
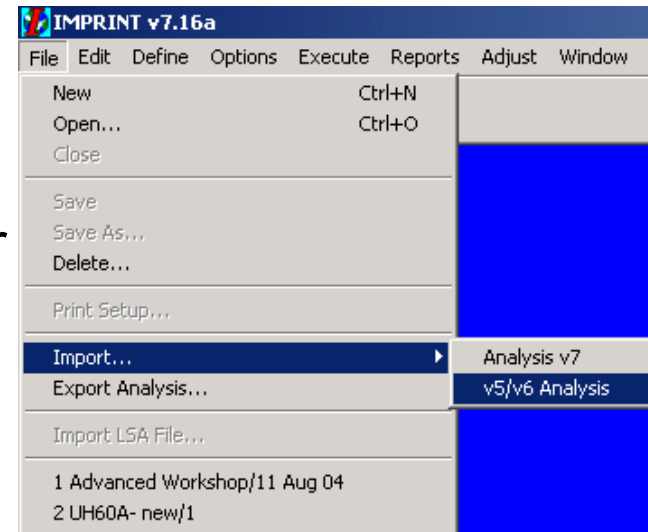
- ◆ To Import a version 7 analysis -
  - Close the open analysis
  - Select “Import - Analysis”
  - Browse until you find the one you’re looking for
  - To access the analysis, you must then open it



***In IMPRINT, it's an analysis. Out of IMPRINT, it's a “.xch” file.***

# Sharing Your Analysis Using Import & Export (cont'd)

- ◆ To Import a version 5 or 6 analysis
  - Close the open analysis
  - Select “Import – 5.0/6.0 Analysis”
  - Browse until you find the one you’re looking for
  - To access the analysis, you must then open it







# Sharing Your Analysis Using Import & Export (cont'd)

## ◆ To Export -

- Close your analysis if you have one open
- Select Export option
- Create export file using Windows naming conventions
- On hard drive or on disk
- File name does not have to = analysis name

The screenshot shows the IMPRINT v7.13a application window. The 'File' menu is open, and 'Export Analysis...' is selected. The 'Export Analysis' dialog box is displayed, showing a list of existing analyses and a file selection window.

**Existing Analysis List:**

Analysis Name	Analysis Version	Last Opened	Mission Area	System Type	System Name
UH60A- new	1	6 / 2 / 2004 09:17:12	Aviation	Utility Helicopter	UH-60A
Sentinel 4	25 May 04	5 / 25 / 2004 12:56:07			
Sentinel	Class 2	5 / 25 / 2004 11:39:52			
workshop	Isa	5 / 25 / 2004 10:33:04			
Diane BLOS	2 Aug 02	5 / 21 / 2004 11:25:37			
Test VTIBaseline	20 Jan 04	5 / 21 / 2004 11:24:39			
tst taxon	1.0	5 / 21 / 2004 11:20:50			
Stuck	1	5 / 21 / 2004 10:19:38			
StressTest	101503	5 / 21 / 2004 10:04:16			
Adjust Wkload-6.25f	Duplicate	5 / 21 / 2004 09:19:33			
VACP Test	13 Mar 02	5 / 21 / 2004 09:06:29			
Maint Stressors	27 Feb 02	5 / 21 / 2004 09:00:25			
Maint Stressor 6Feb02	14 Feb 02	5 / 21 / 2004 08:08:18			

**Export to:**

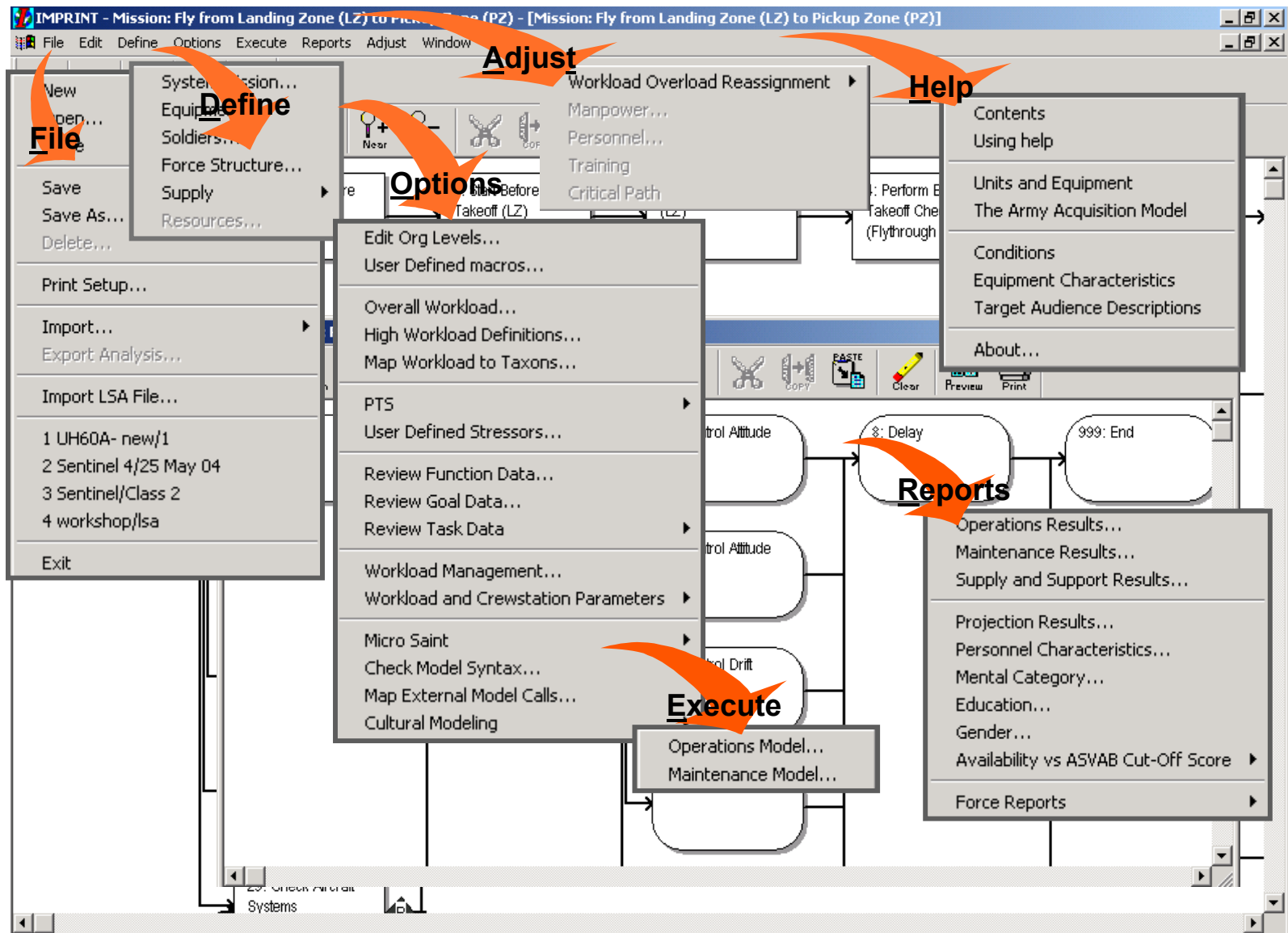
Save in: import\_export

File name: VACP-Exercise-new

Save as type: \*.xch

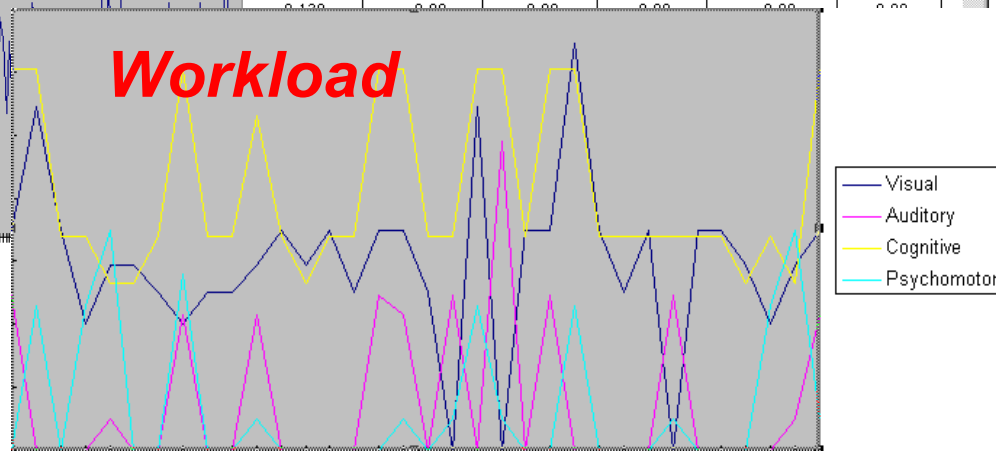
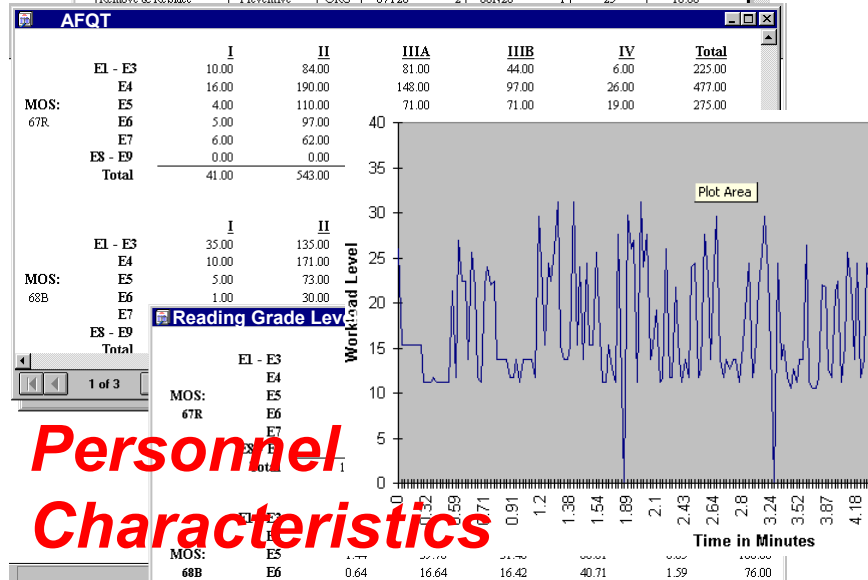
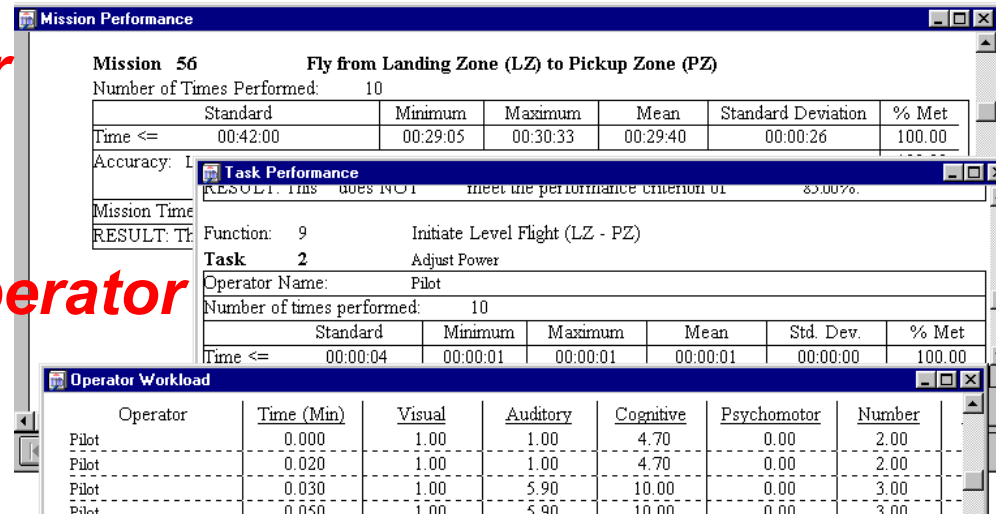
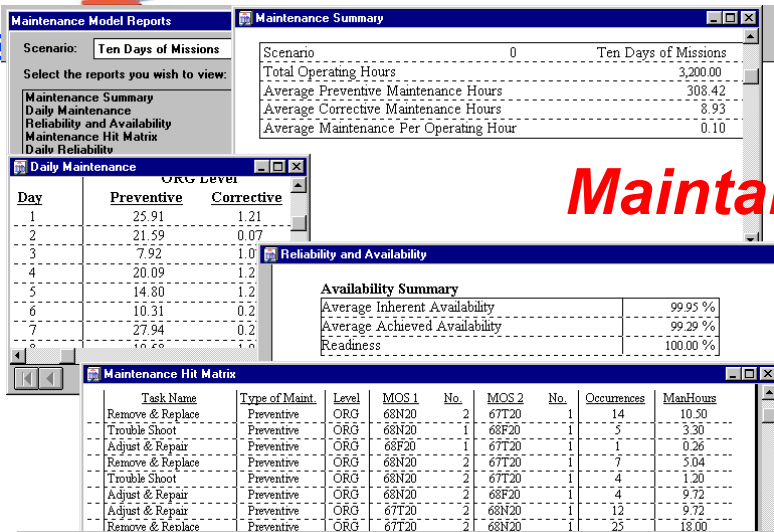
Buttons: Save, Cancel

# IMPRINT Menus





# IMPRINT Reports



# *Define Mission*



# *Define Mission Answers...*

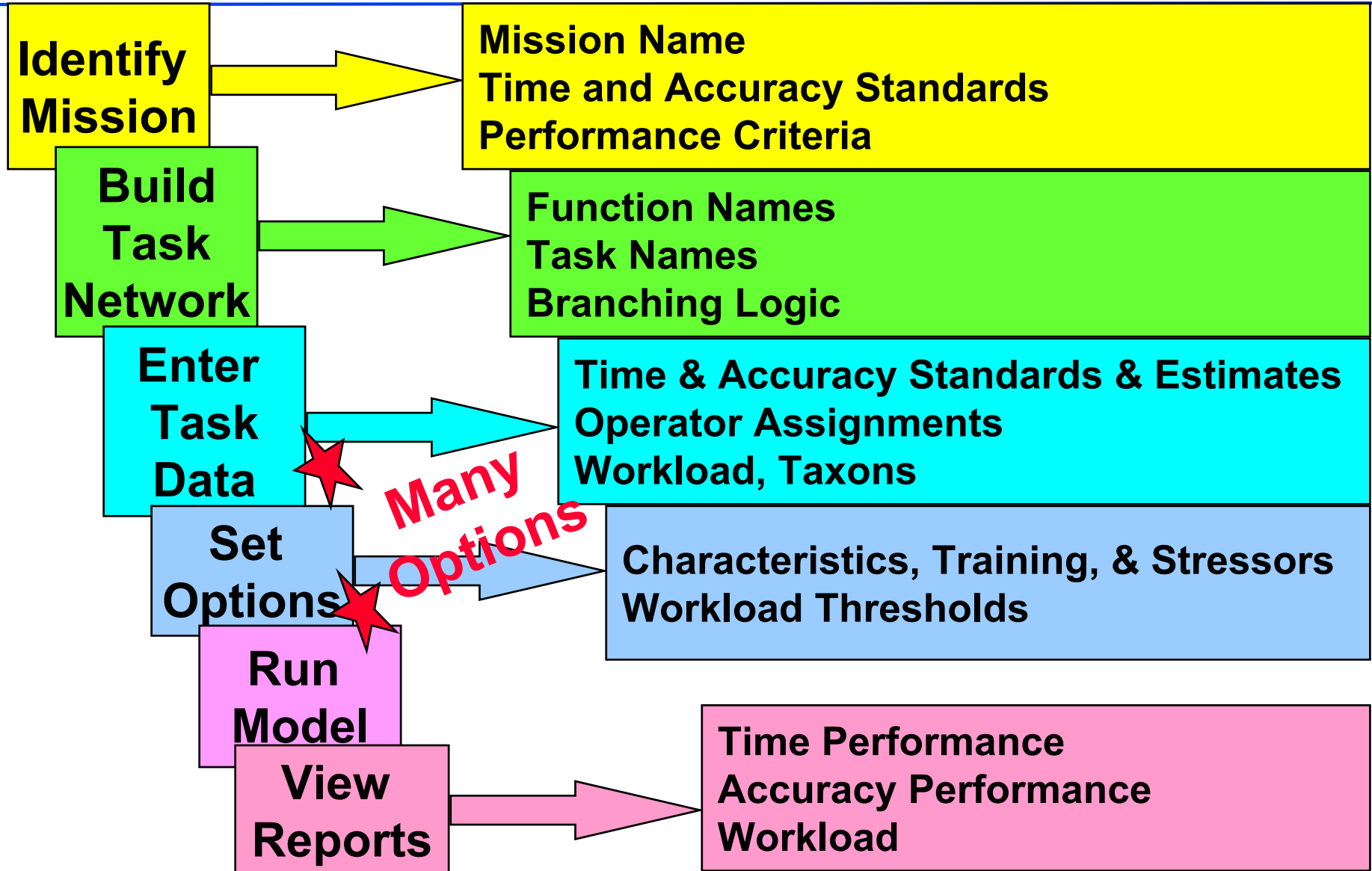
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- ◆ How long will it take to perform my tasks?
- ◆ How much workload will be created?
- ◆ What is the probability of success?
- ◆ How should tasks be allocated across crewmembers and to automation?

# *Define Mission Inputs*

- ◆ Mission level
  - time standard
  - time criterion
  - accuracy criterion
  - mission criterion
- ◆ Function level
  - time standard
  - time criterion
- ◆ Branching logic
  - serial
  - multiple
  - repeating
  - probabilistic
- ◆ Task level
  - time standard
  - accuracy standard
  - criterion
  - time estimate
  - accuracy estimate
  - consequences of failure
  - workload
  - taxons
  - crew assignments

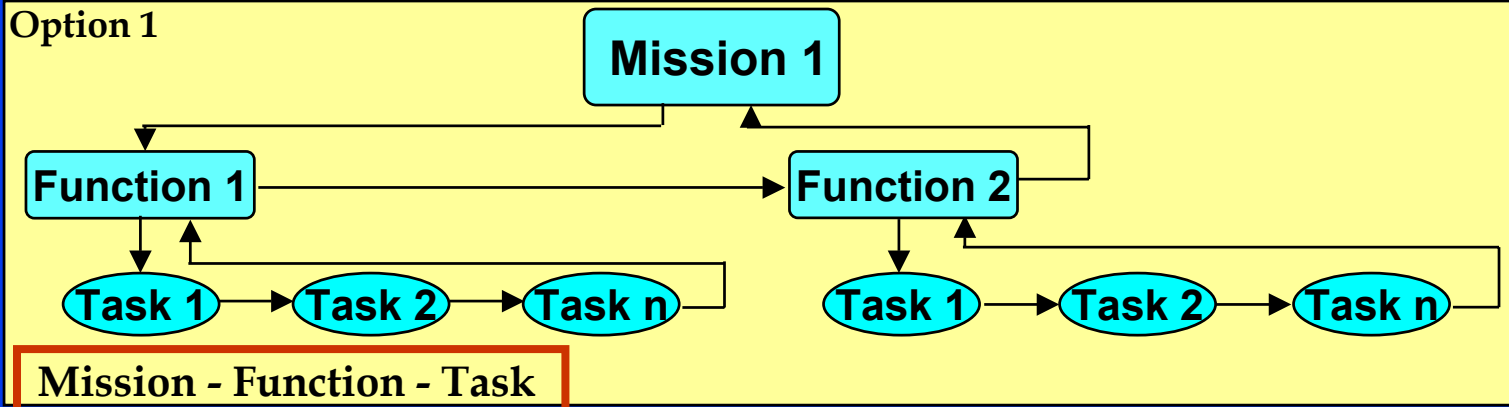
# *Define Mission Process*



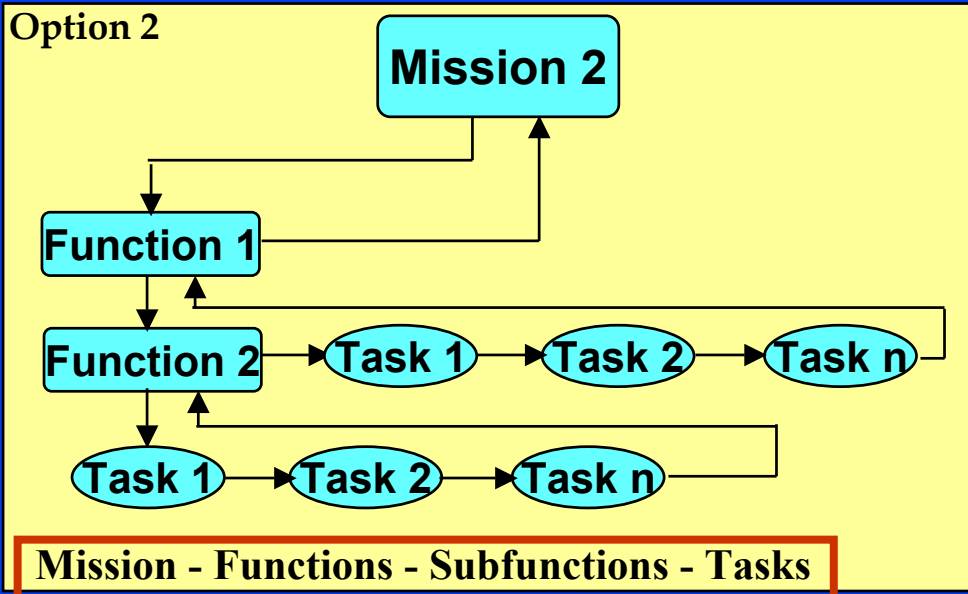
# Task Network Hierarchy Options in VACP

## System

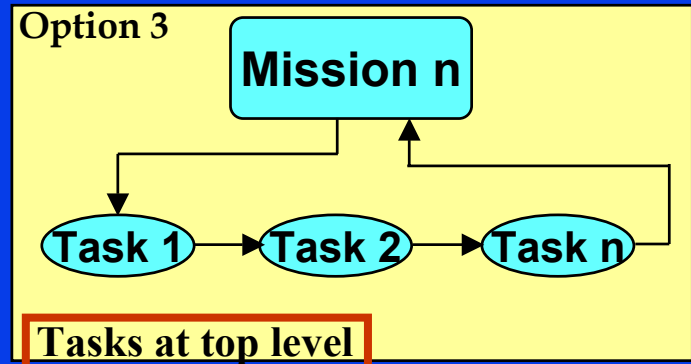
Option 1



Option 2



Option 3







## *Define Mission*

- ◆ Micro Saint-based modeling tool
- ◆ Designed specifically for human operators of systems
- ◆ Evaluate system performance time and/or accuracy
- ◆ Has workload computations built-in
- ◆ Has data collection built-in

# Task Network Toolbar



selects a node

displays next level down

goes back to parent function

draws a path

erases a path

places a function node

places a task node

zooms in

zooms out

cuts a node (can paste)

copies a node

pastes a node

clears a node (can't paste)

shows page layout

prints the diagram

- ◆ Time
  - Standard
  - Mean & Standard Deviation
  - Micromodels
- ◆ Accuracy
  - Standard
  - Probability of Success
  - Mean & Standard Deviation
  - Consequences of Failure
- ◆ Operator assignments
- ◆ Workload
- ◆ Taxons

# *Assign Operators to Tasks*



- ◆ Primary
  - Performs task regardless of current workload
- ◆ Secondary (Optional)
  - Has requisite skills and training
  - Used to recommend task reallocations

## Execute Operations Model

Mission:

Number of times to run the mission:

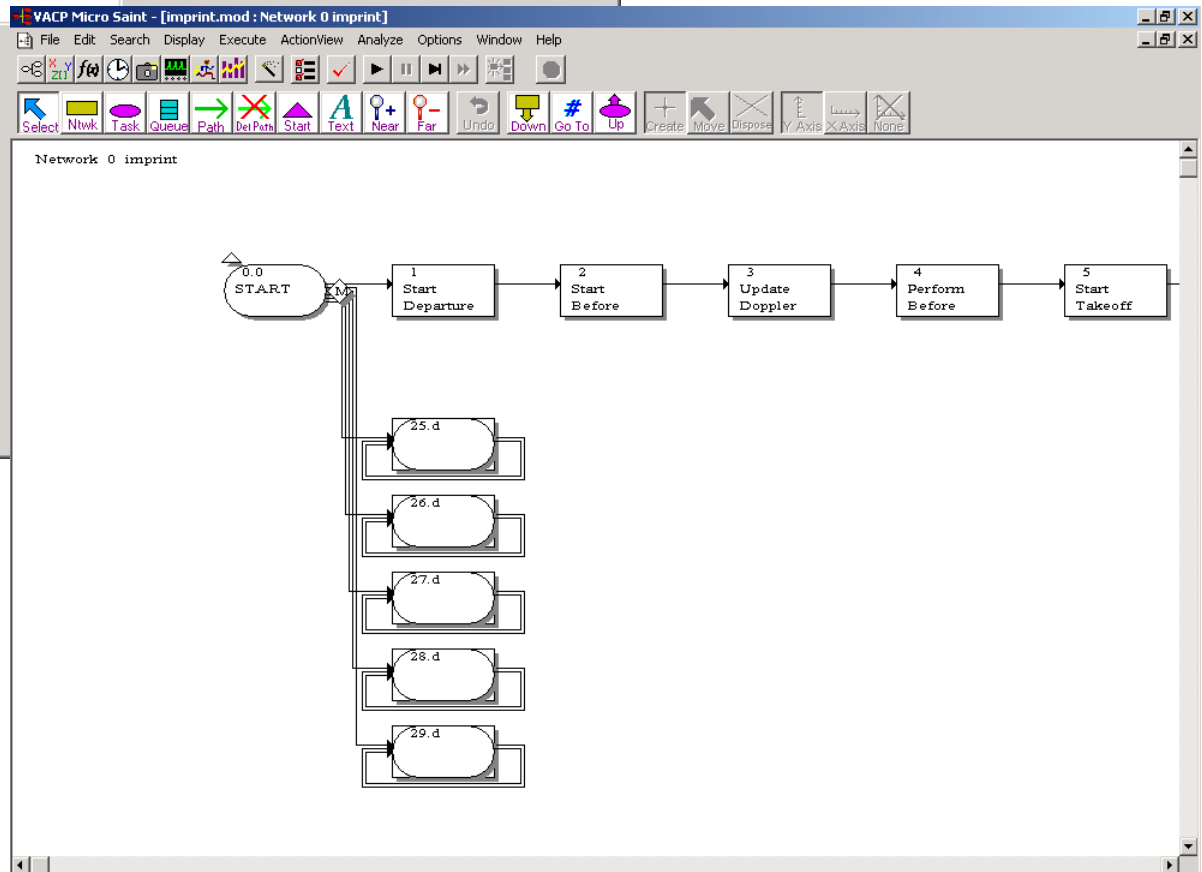
Random Number Seed:



☒ Animation

☐ PTS Adjustments

☐ Perfect Accuracy



# *Outputs of Define Mission*

- ◆ Mission Performance
  - Predicted time & success rate
- ◆ Function Performance
  - Predicted time
- ◆ Task Performance
  - Predicted time & accuracy
- ◆ (And others you will see later)



# *Cashier Model*

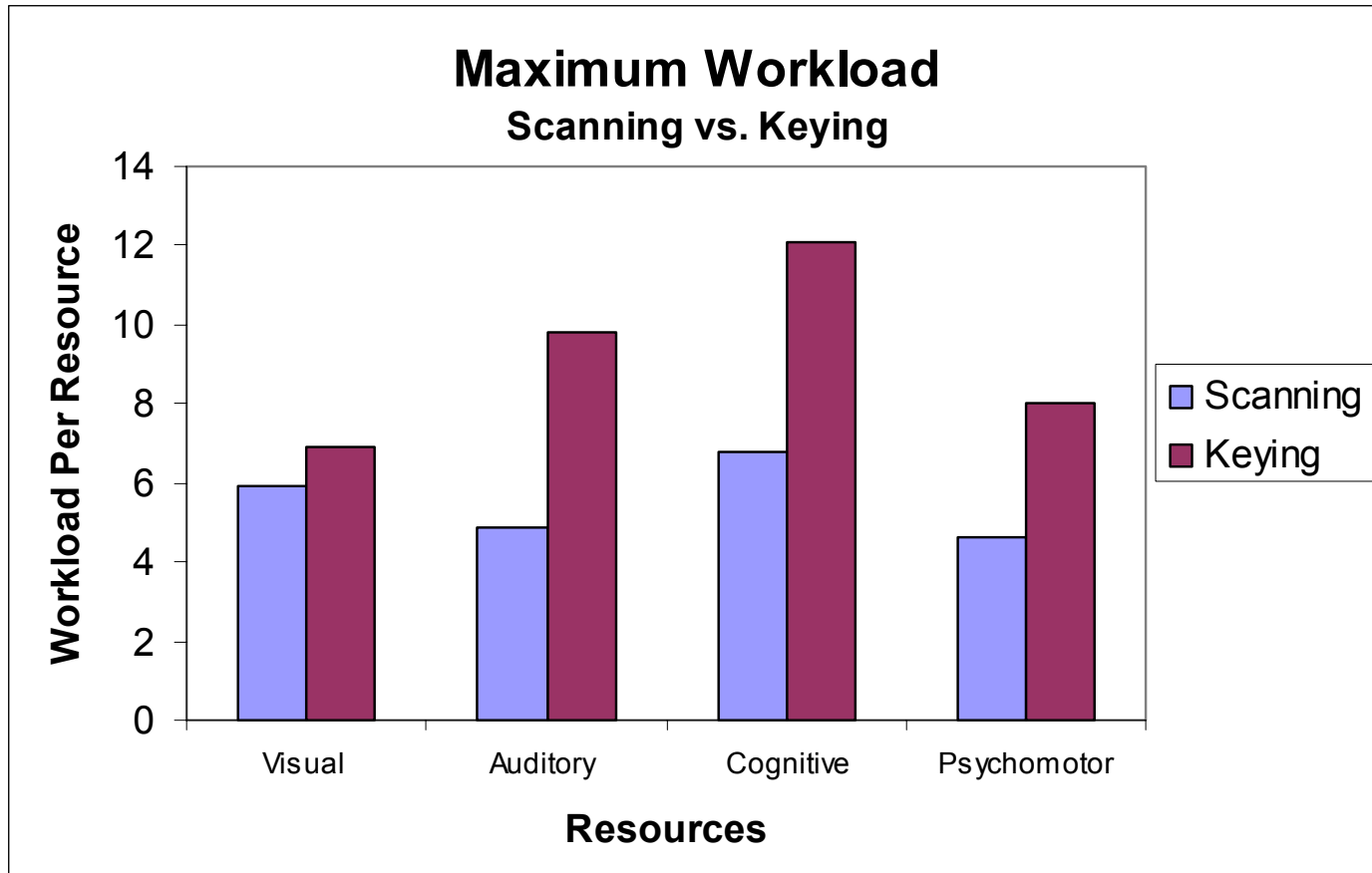
# Results - Spreadsheets

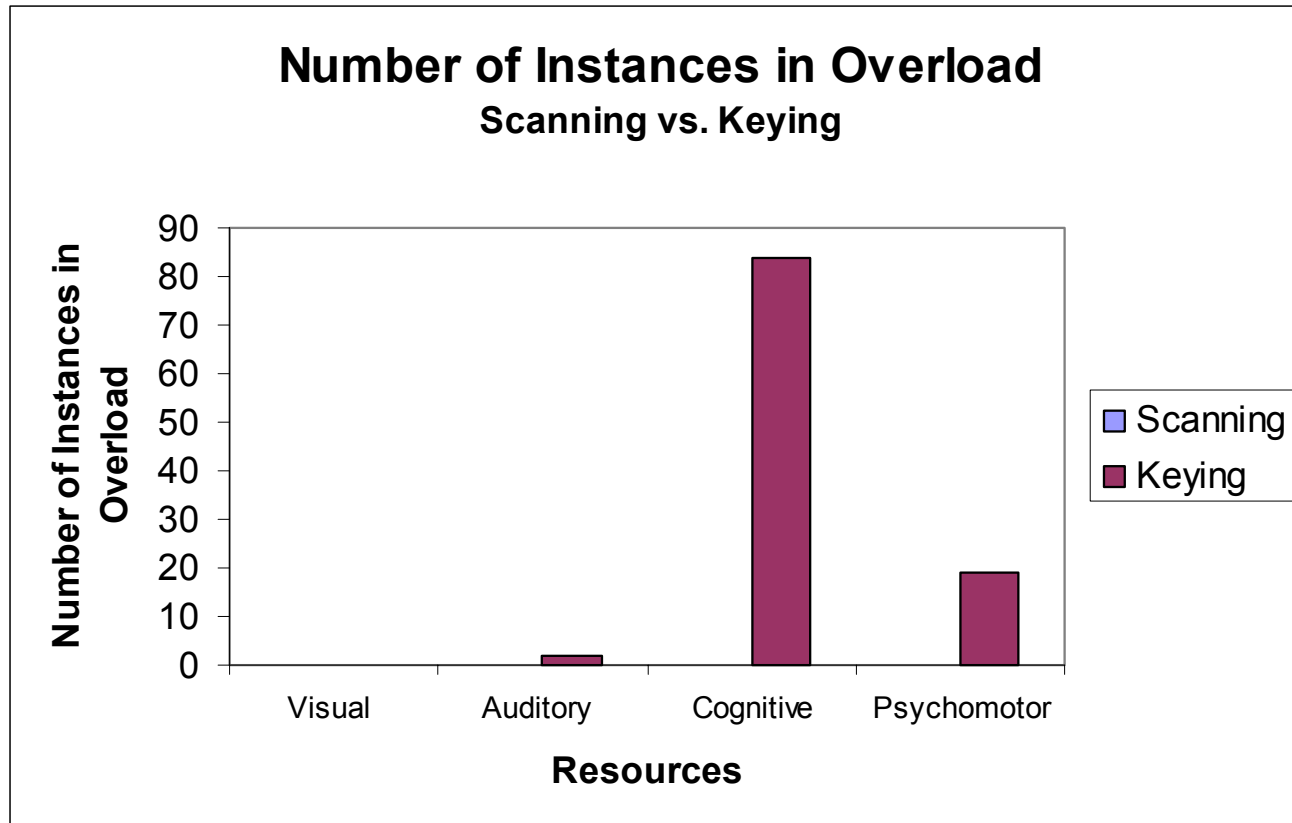
			Operator Workload			
System:			March 31, 2003			
Mission:	Cha tty Ca shie r ke ying ite ms					
Operator	Time	Vis ua l	Aud itory	Cognitive	Ps ychomotor	Ove ra ll
Ca shie r	00:00:00.00	1	1	1	1	4
Ca shie r	00:00:00.70	3.7	4.9	1	1	10.6
Ca shie r	00:00:03.10	6	4.9	6.3	5.6	22.8
Ca shie r	00:00:04.60	6	5.9	9	8	28.9
Ca shie r	00:00:06.10	6	5.9	9	8	28.9
Ca shie r	00:00:06.70	5	4.9	12.1	5.6	27.6
Ca shie r	00:00:06.76	4.7	4.9	9.9	1	20.5
Ca shie r	00:00:06.84	2	4.9	6.3	5.6	18.8
Ca shie r	00:00:06.94	6	4.9	6.3	5.6	22.8
Ca shie r	00:00:08.44	6	5.9	9	8	28.9
Ca shie r	00:00:09.10	6	5.9	9	8	28.9
Ca shie r	00:00:10.53	5	4.9	12.1	5.6	27.6
Ca shie r	00:00:10.60	2	4.9	5.3	5.6	17.8
Ca shie r	00:00:11.10	4.7	4.9	6.3	5.6	21.5
Ca shie r	00:00:12.10	2	4.9	6.3	5.6	18.8
Ca shie r	00:00:12.20	6	4.9	6.3	5.6	22.8
Ca shie r	00:00:13.70	6	5.9	9	8	28.9
Ca shie r	00:00:15.10	6	5.9	9	8	28.9
Ca shie r	00:00:15.79	5	4.9	12.1	5.6	27.6
Ca shie r	00:00:15.85	4.7	4.9	9.9	1	20.5
Ca shie r	00:00:15.93	2	4.9	6.3	5.6	18.8
Ca shie r	00:00:16.03	6	4.9	6.3	5.6	22.8



	Max Value		Instances in Overload	
			(# of times >7)	
Resources	Scanning	Keying	Scanning	Keying
Visual	5.9	6.9	0	0
Auditory	4.9	9.8	0	2
Cognitive	6.8	12.1	0	84
Psychomotor	4.6	8	0	19

# Results - charts





# *Develop Your Own Analysis*

# Develop Your Own Analysis

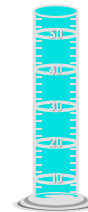
◆ Pick a Topic



◆ Develop a Question and Hypothesis



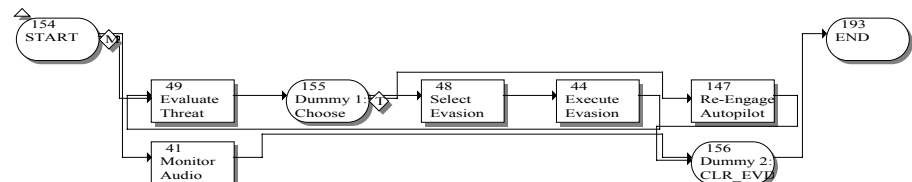
◆ Determine Measures



◆ Identify Functions and Tasks



◆ Build your Model



# *Your Model Analysis*

# *Does Your Model Run?*



**Yeah!!**



**So What???**

# *Your Model Runs – So What?*

---

- ◆ **Did it do what you wanted it to?**
  - First step is verification and debugging
- ◆ **How are you going to evaluate the results?**
  - Complete the analysis step
- ◆ **Is this realistic?**
  - Validate the model



## Verification, Validation, and Accreditation vs. Verification, Analysis, Validation, and Accreditation

- **Verification** means determining that the model does what it was meant to do
- **Analysis** of results means evaluating the results
- **Validation** means the model adequately represents the system
- **Accreditation** means that the model has been accredited for the use case

# *Tow Company - Example*

They change a lot of tires. The number of tires changed equates to income. Maybe technology will help.

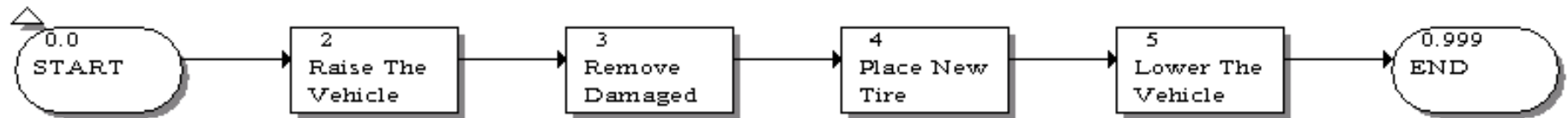
Questions: How long does it take to change a tire?  
Where are the most errors made?

First step was to do a task analysis of tire changing and collect time and accuracy data.

Build a model.



# *Tire Change Model*





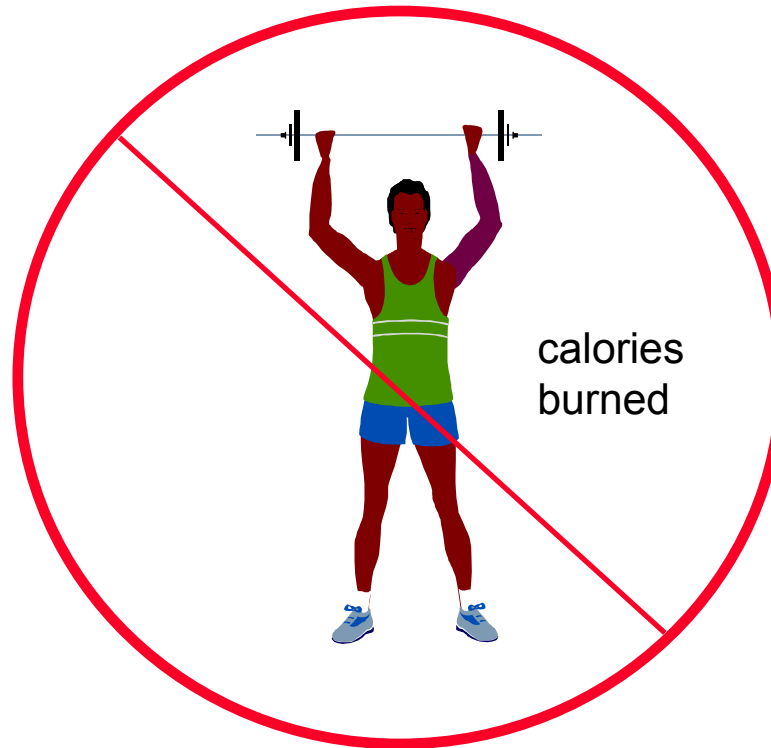
# Tire Change Model – 10 runs

Task	No of times normally executed in a run	No. of Times Executed	Time Std	Mean Time	Std Dev	met Time Std.	Accuracy Std	met Accuracy Std.	Performance Criterion	met Criterion	Failed Criterion	mission aborts
Locate jack point	1	13	45	30.9	7.8	100	92	76.92	90	76.92	yes	
place jack	1	12	30	10.2	3.06	100	85	83.33	90	83.33	yes	
raise car	1	10	20	14.58	2.34	100	95	100	90	100	no	
loosen lug nuts	6	96	20	10.26	2.88	100	80	59.38	90	59.38	yes	1
raise car	1	9	20	11.64	3.84	100	95	100	90	100	no	
remove lug nuts	6	54	20	9.84	5.1	94.44	90	100	90	94.44	no	
remove tire	1	9	20	11.58	2.4	100	95	100	90	100	no	
align tire	1	10	20	11.04	3.48	100	90	100	90	100	no	
lift and place	1	10	15	5.82	2.64	100	90	90	90	90	no	
hand tighten lug nuts	6	77	30	13.68	5.64	100	75	70.13	90	70.13	yes	
lower vehicle	1	9	20	10.92	3.72	100	95	100	90	100	no	
remove jack	1	9	10	5.58	1.56	100	95	100	90	100	no	
tighten lug nuts	6	69	30	15.42	4.68	100	95	78.26	90	78.26	yes	
Mission	1	10	9:00	8:37.98	51.72	70		90	95	60	yes	

# Tire Change Model – 30 runs

Task	No of times normally executed in a run	No. of Times Executed	Time Std	Mean Time	Std Dev	met Time Std.	Accuracy Std	met Accuracy Std.	Performance Criterion	met Criterion	Failed Criterion	mission aborts
Locate jack point	1	34	45	29.46	12.6	94.12	92	88.54	90	82.35	yes	
place jack	1	56	30	10.02	3.12	100	85	53.57	90	53.57	yes	
raise car	1	30	20	15.54	4.56	86.67	95	100	90	86.57	yes	
loosen lug nuts	6	279	20	9.78	3.3	100	80	61.65	90	61.65	yes	3
raise car	1	28	20	10.44	3.48	100	95	96.43	90	96.43	no	
remove lug nuts	6	164	20	10.02	5.04	96.34	90	98.78	90	95.12	no	
remove tire	1	27	20	10.56	3.66	100	95	100	90	100	no	
align tire	1	34	20	10.8	4.2	97.06	90	91.18	90	88.24	yes	
lift and place	1	34	15	5.16	2.4	100	90	79.41	90	79.41	yes	
hand tighten lug nuts	6	162	30	14.82	4.62	99.53	75	76.42	90	75.94	yes	
lower vehicle	1	27	20	8.22	3.78	100	95	100	90	100	no	
remove jack	1	27	10	4.62	1.8	100	95	100	90	100	no	
tighten lug nuts	6	179	30	14.94	4.74	100	95	86.03	90	86.03	yes	3
Mission	1	30	9:00	8:16.02	52.98	83.33		80	95	63.33	yes	

# *Workload Concepts*



# *What Is Mental Workload?*

## An Example

- ◆ Drivers slowing down to talk on their cell phone
- ◆ Accident rates of drivers using cell phones approaches that of drivers under the influence of alcohol







# *Why You Should Care About Workload*

- ◆ If you reduce crewsize then some tasks must be automated or redistributed among remaining crew positions
  - Reallocation of tasks is likely to increase workload, thus increasing the potential for performance failures and errors.
  - Poorly designed automation can also increase workload and thus the potential for human errors.



# *Mental Workload Issues*

- ◆ Sustained low workload (underload) leads to boredom, loss of situation awareness, and reduced alertness.
- ◆ Sustained high workload (overload) leads to fatigue.
- ◆ Workload peaks lead to dropped tasks, increased task time, cognitive tunneling, and increased errors.
- ◆ These factors reduce crew performance, system performance, and contribute to mission failure

# *Mental Workload Objective*

Achieve evenly distributed, manageable workload.

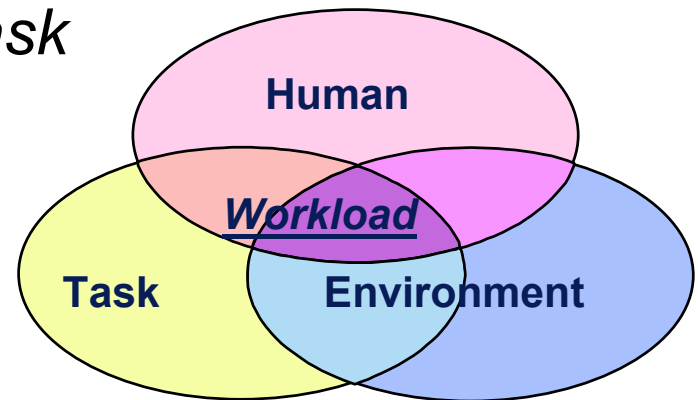


Avoid both overload and underload.



## ◆ Workload Definition

- There is no universally agreed-upon definition
- Today, however, there is generally agreement that, essentially, workload is
  - » *the perceived relationship between the amount of mental processing capacity or resources and the amount required by the task*





# *Various Mental Workload Measurement Approaches*

## **empirical**

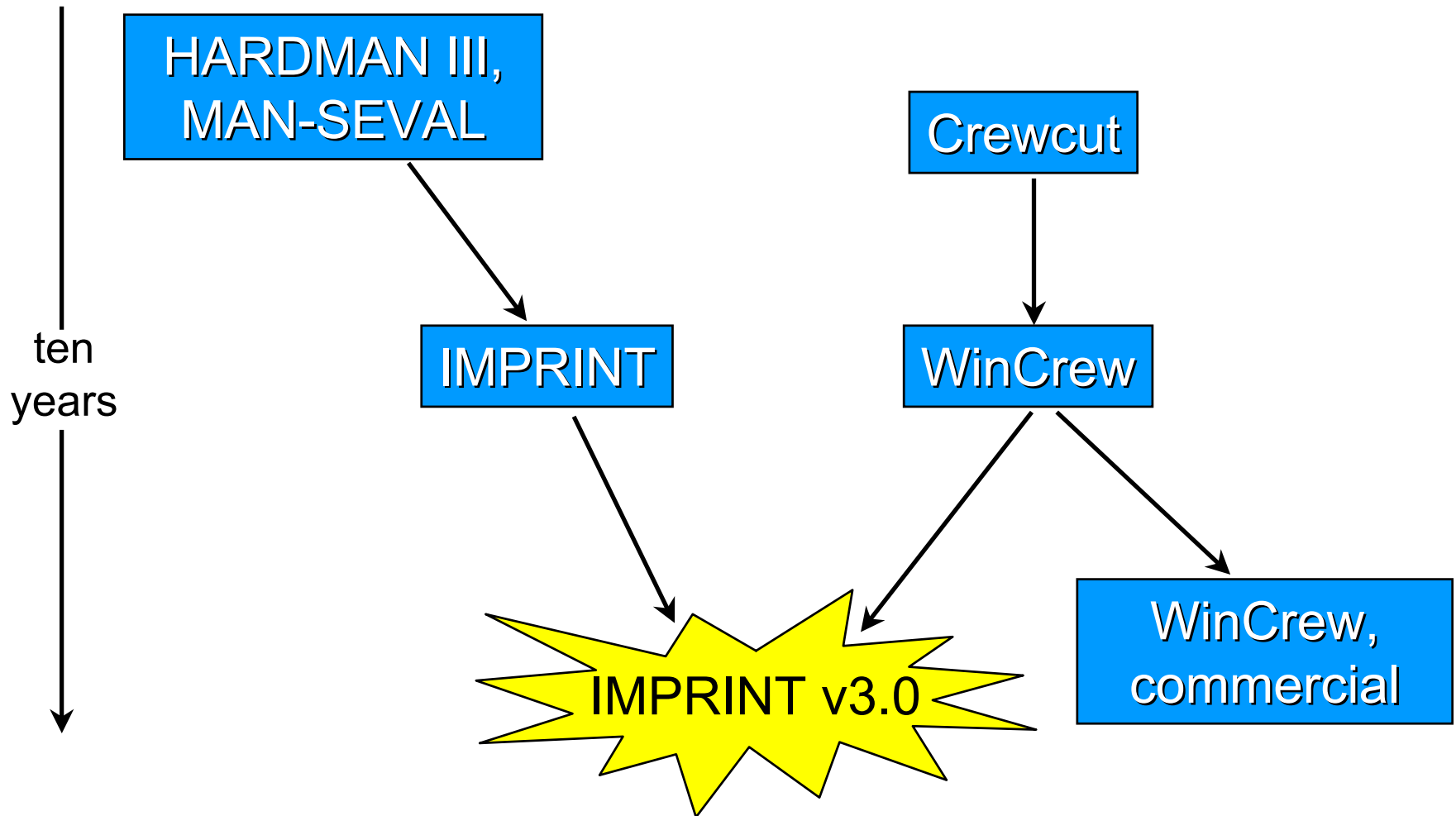
- ◆ physiological
- ◆ primary task
- ◆ secondary task
- ◆ subjective rankings

## **analytical**

- ◆ workload modeling-  
IMPRINT

- ◆ Workload modeling of human behavior is a technique that has been used to *predict* workload levels.
  - IMPRIINT can be used to model and predict mental workload.

# ARL HRED Workload Modeling Tools



# *VACP Workload*



# *VACP Workload Method*

---

- ◆ AKA “McCracken-Aldrich
- ◆ Four independent channels
- ◆ Overload defined as any channel  $> 7$
- ◆ Option to combine into “Overall” channel

# Multiple Resources Theory of Mental Workload

**Mission  
Tasks**



**Which Brain  
Resources  
Involved?**



**Degree of  
Resource Use?**

1. monitor  
alarms

2. decide  
response  
action

3. pull trigger

•  
•  
•

n. task n

**Visual**

**Cognitive**

**Auditory**

**Psychomotor**



**Visual**

**Auditory**

**Psychomotor**

**Cognitive**

- 0.0 No Cognitive Activity
- 1.0 Automatic (simple association)
- 1.2 Alternative Selection
- 3.7 Sign/Signal Recognition
- 4.6 Evaluation/Judgment (consider single aspect)
- 5.3 Encoding/Decoding, Recall
- 6.8 Evaluation/Judgment (consider several aspects)
- 7.0 Estimation, Calculation, Conversion



# Assign Workload

## Visual

- 0.00 No Visual Activity
- 1.00 Visually Register/Detect (detect image)
- 3.70 Visually Discriminate (detect visual differences)
- 4.00 Visually Inspect/Check (static inspection)
- 5.00 Visually Locate/Align (selective orientation)
- 5.40 Visually Track/Follow (maintain orientation)
- 5.90 Visually Read (symbol)
- 7.00 Visually Scan/Search/Monitor(continuous)

## Auditory

- 0.00 No Auditory Activity
- 1.00 Detect/Register Sound
- 2.00 Orient to Sound (general orientation)
- 4.20 Orient to Sound (selective orientation)
- 4.30 Verify Auditory Feedback
- 4.90 Interpret Semantic Content (speech)
- 6.60 Discriminate Sound Characteristics
- 7.00 Interpret Sound Patterns (pulse rate, etc.)

## **Cognitive**

- 0.00 No Cognitive Activity
- 1.00 Automatic (simple association)
- 1.20 Alternative Selection
- 3.70 Sign/Signal Recognition
- 4.60 Evaluation/Judgment (consider single aspect)
- 5.30 Encoding/Decoding, Recall
- 6.80 Evaluation/Judgment (consider several aspects)
- 7.00 Estimation, Calculation, Conversion

## **Psychomotor**

- 0.00 No Psychomotor Activity
- 1.00 Speech
- 2.20 Discrete Actuation (button, toggle, trigger)
- 2.60 Continuous Adjustive (flight or sensor control)
- 4.60 Manipulative
- 5.80 Discrete Adjustive (rotary, thumbwheel, lever)
- 6.50 Symbolic Production (writing)
- 7.00 Serial Discrete Manipulation (keyboard entries)



# *Subjective Assessment & Prediction: McCracken-Aldrich*

- ◆ Originally developed for the LHX single-pilot helicopter program
- ◆ Consistent with Wickens multiple-resource theory
- ◆ Four original scales
  - Visual
  - Auditory
  - Cognitive
  - Psychomotor



# “High Workload” and Reallocation

- ◆ Under “Options,” define up to 5 high workload thresholds
- ◆ When model runs, points where one or more thresholds are exceeded will be reported
- ◆ Under “Adjust,” workload overload points can be reviewed, and assigned to a secondary operator if desired
- ◆ Then re-run model to re-check workload

*(Be sure to save your original model before reallocating)*

*(And remember, workload does not dynamically affect performance here)*

The screenshot shows the IMPRINT v7.13a software interface. The title bar reads "IMPRINT v7.13a - Analysis: UH60A- new Version: 1 Mission: Fly from Landing Zone (LZ) to Pickup Zone (PZ)". The menu bar includes File, Edit, Define, Options, Execute, Reports, Adjust, Window, and Help. The main window is titled "High WorkLoad".

Under the "Mission" section, the text "Fly from Landing Zone (LZ) to Pickup Zone (PZ)" is displayed.

The "Workload Channel" section contains a list of workload categories, each with a checkbox, a greater-than symbol, a text input field, and the word "AND":

- ☐ Visual [V] > [ ] AND
- ☐ Auditory [A] > [ ] AND
- ☐ Cognitive [C] > [ ] AND
- ☐ Psychomotor [P] > [ ] AND
- ☐ Overall [O] > [ ] AND
- ☐ Number of ongoing Tasks [N] > [ ] AND

To the right of this list is a button labeled "Add To Threshold List".

The "Thresholds:" section at the bottom has four rows, each with a text input field and a "Clear" button:

- Thresholds: [ ] Clear
- OR: [ ] Clear
- OR: [ ] Clear
- OR: [ ] Clear

On the right side of the "Thresholds:" section are three buttons: "Ok" (with a green checkmark icon), "Cancel" (with a red X icon), and "Help" (with a question mark icon).

# *Analysis of Results*

# *FCS - 2 Vs. 3 Trade Study*





# *FCS Modeling Team*

---

Diane Mitchell

diane@arl.army.mil  
(410) 278-5878

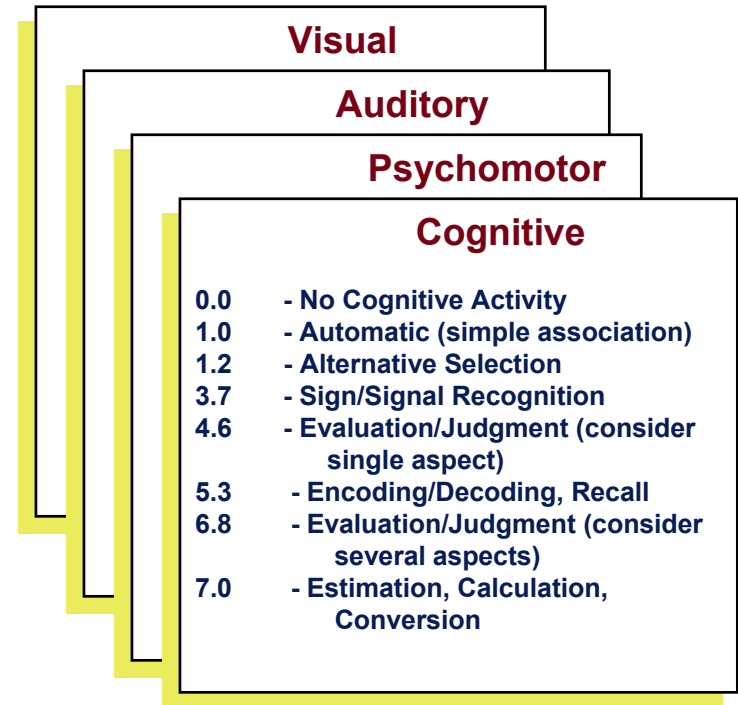
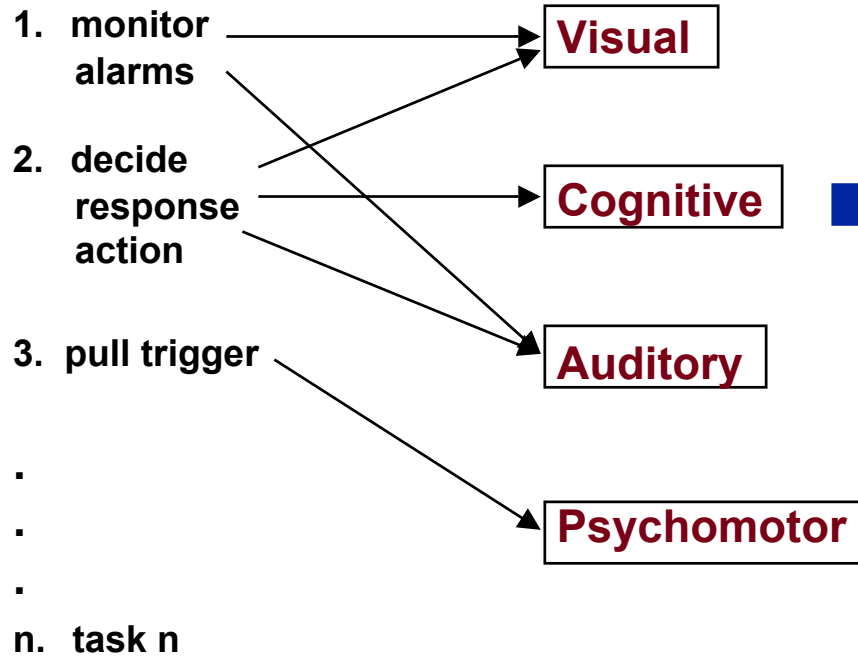
Charneta Samms

csamms@arl.army.mil  
(410) 278-5877

Jody Wojciechowski

jqw@arl.army.mil  
(410) 278-8830

# Mental Workload





# *Common Military Functions*

## **Common Functions in Modeling Military Systems**

***Communicate  
information***

***Drive  
vehicle***

***Scan for  
targets***

***Command  
troops***

***Identify  
targets***

***Shoot  
targets***

***Maintain situation  
awareness***



# *FCS Modeling Approach*

---

Four IMPRINT combat models:

Gunner-Driver and Commander

Commander-Driver and Gunner

Commander-Gunner and Driver

Commander, Driver and Gunner

# Crew Member Function Allocation

Function Name	Condition 1 GD and C	Condition 2 CD and G	Condition 3 CG and D	Condition 4 C and G and D
	<i>Function allocation</i>	<i>Function allocation</i>	<i>Function allocation</i>	<i>Function allocation</i>
Drive	GD	CD	D	D
Hindrance	GD	CD	D	D
Remediate	GD	CD	D	D
Engage	GD <sup>(C)</sup>	G <sup>(CD)</sup>	CG	G <sup>(C)</sup>
Scan	C	G	CG	C and G
External Com	C	CD	CG	C
Crew Commo	GD & C	CD & G	CG & D	C & G & D

# *FCS Modeling Results Summary*

## **Commander - Driver and Gunner**

Highest workload of all conditions



## **Gunner - Driver and Commander**

No shooting on the move



## **Commander - Gunner and Driver**

Best two crewmember function allocation; single vehicle commander

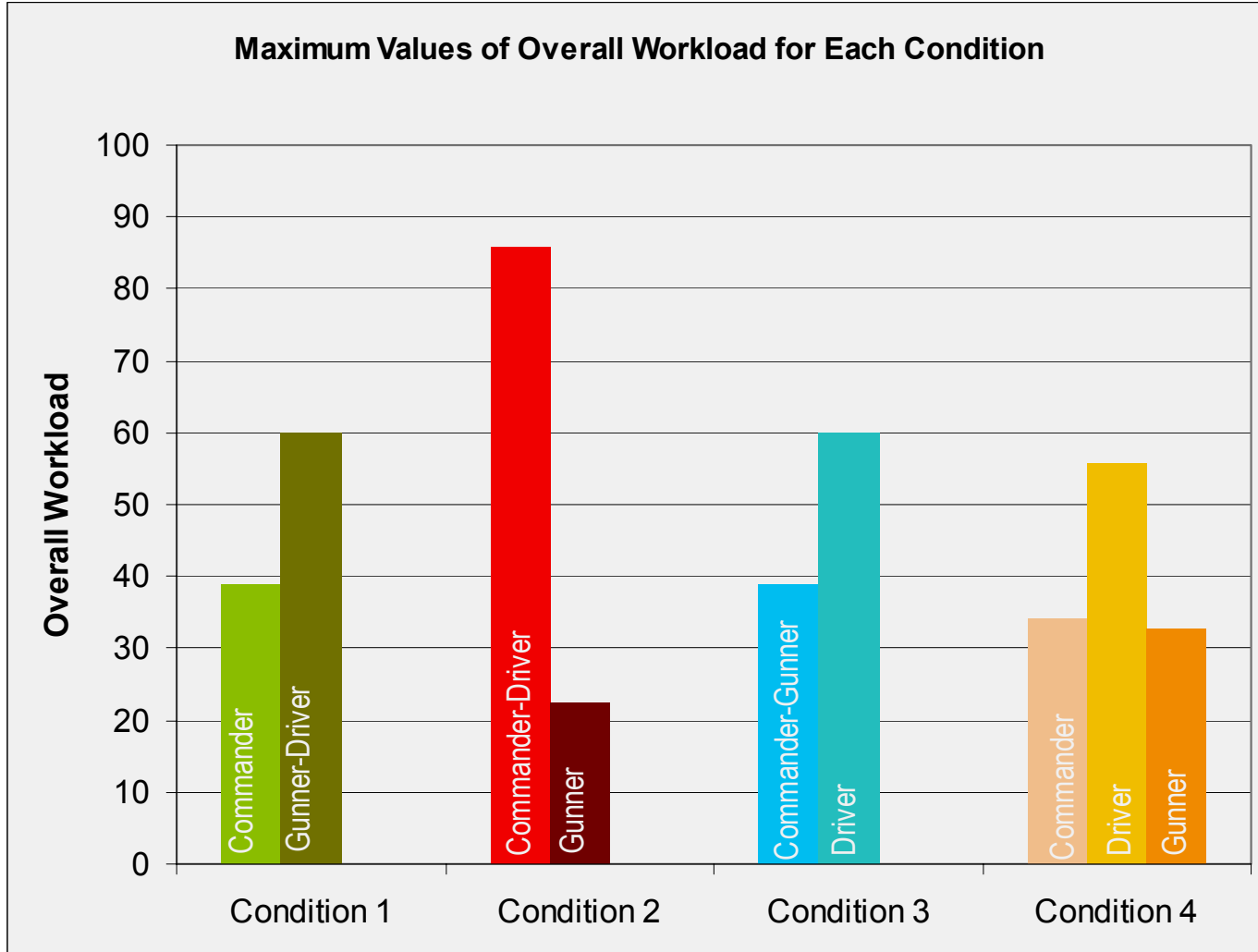


## **Commander, Driver and Gunner**

Two crewmembers scanning; allows hunter-killer philosophy

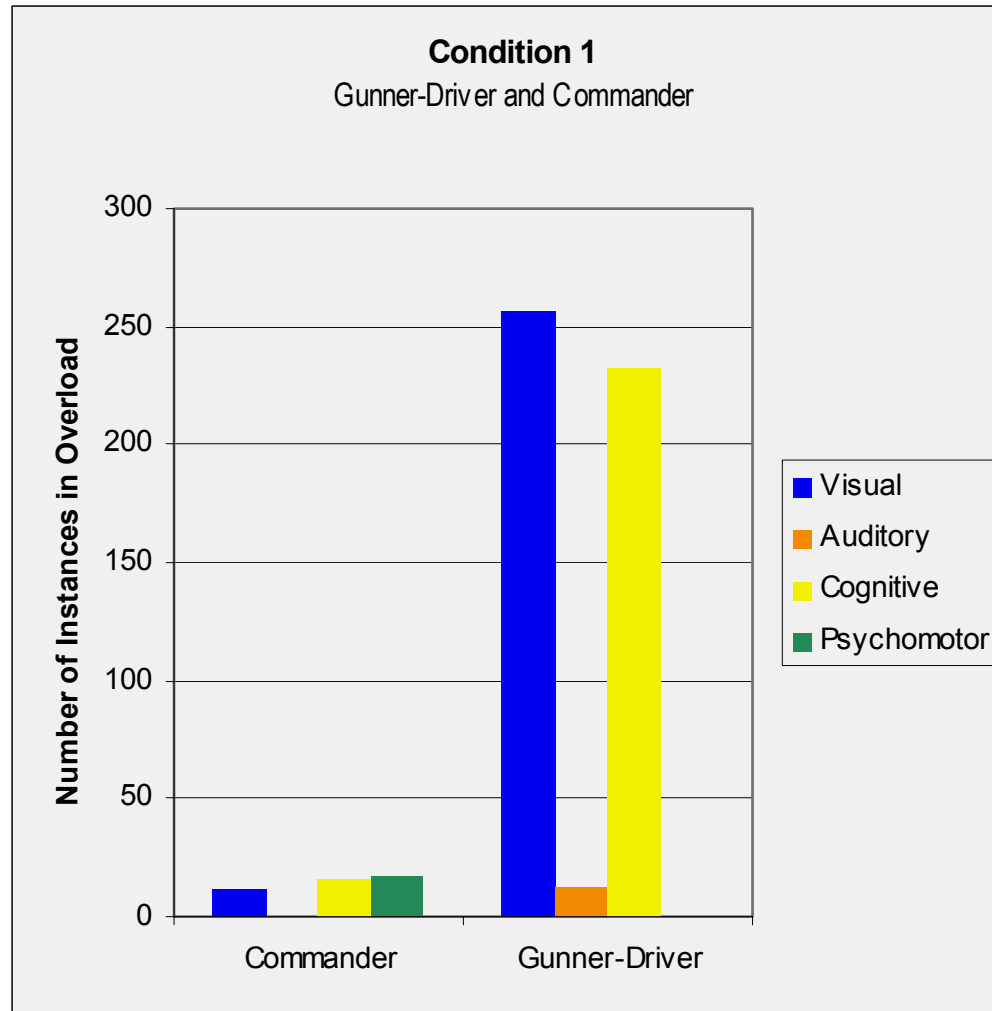
# *Data Tables*

# *FCS Modeling Results*

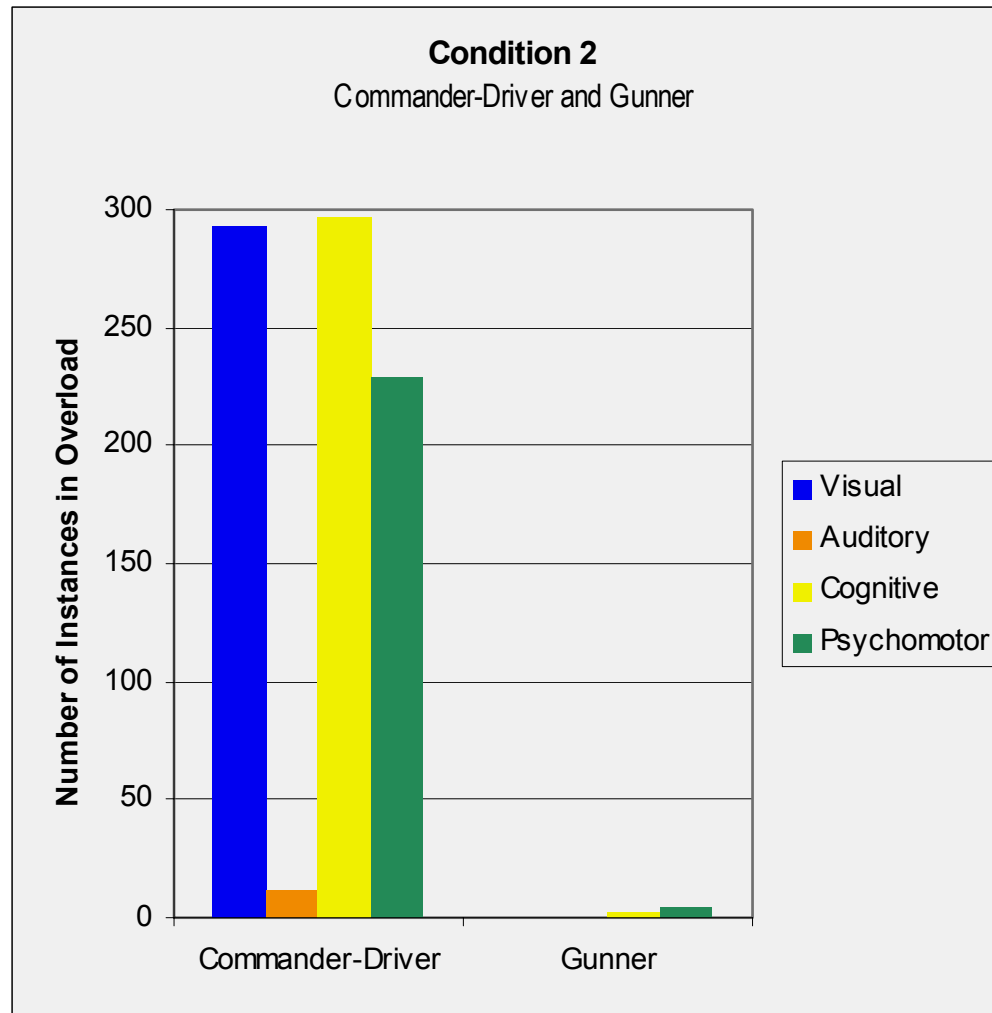




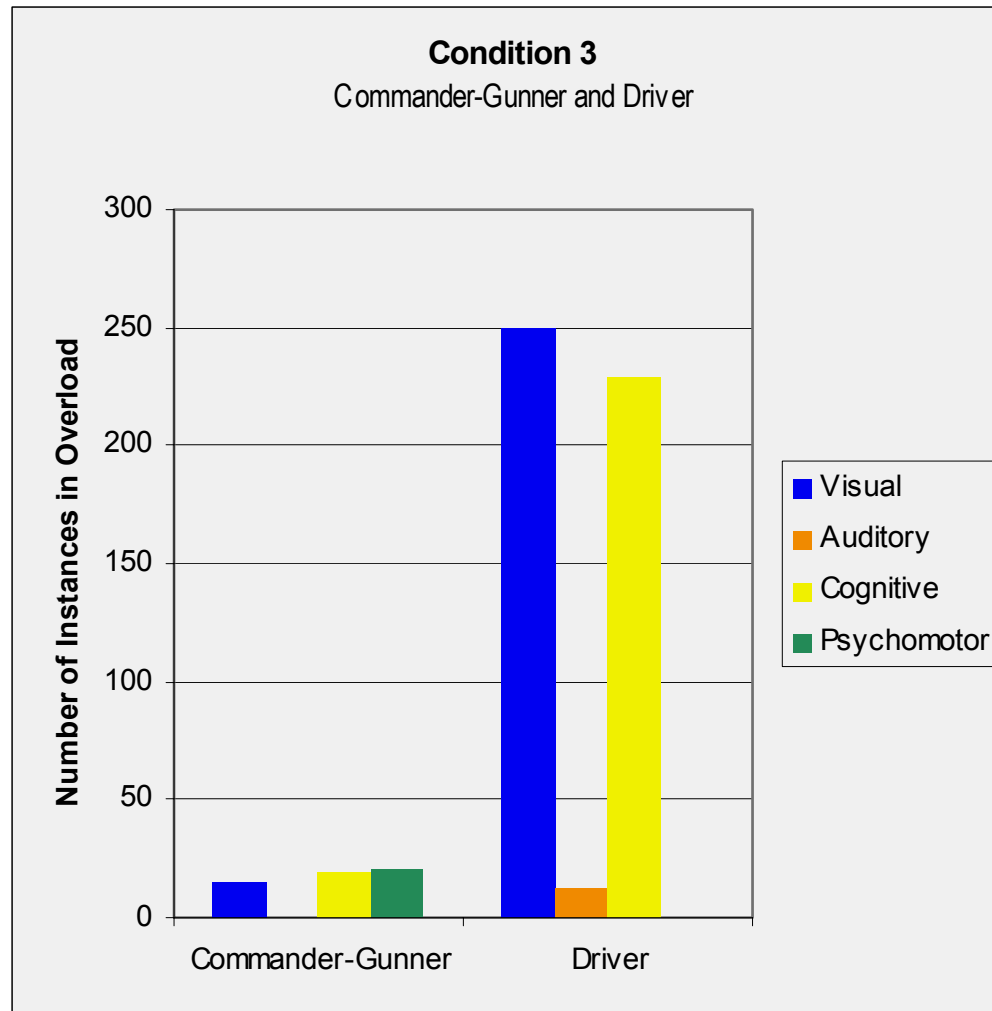
# FCS Modeling Results



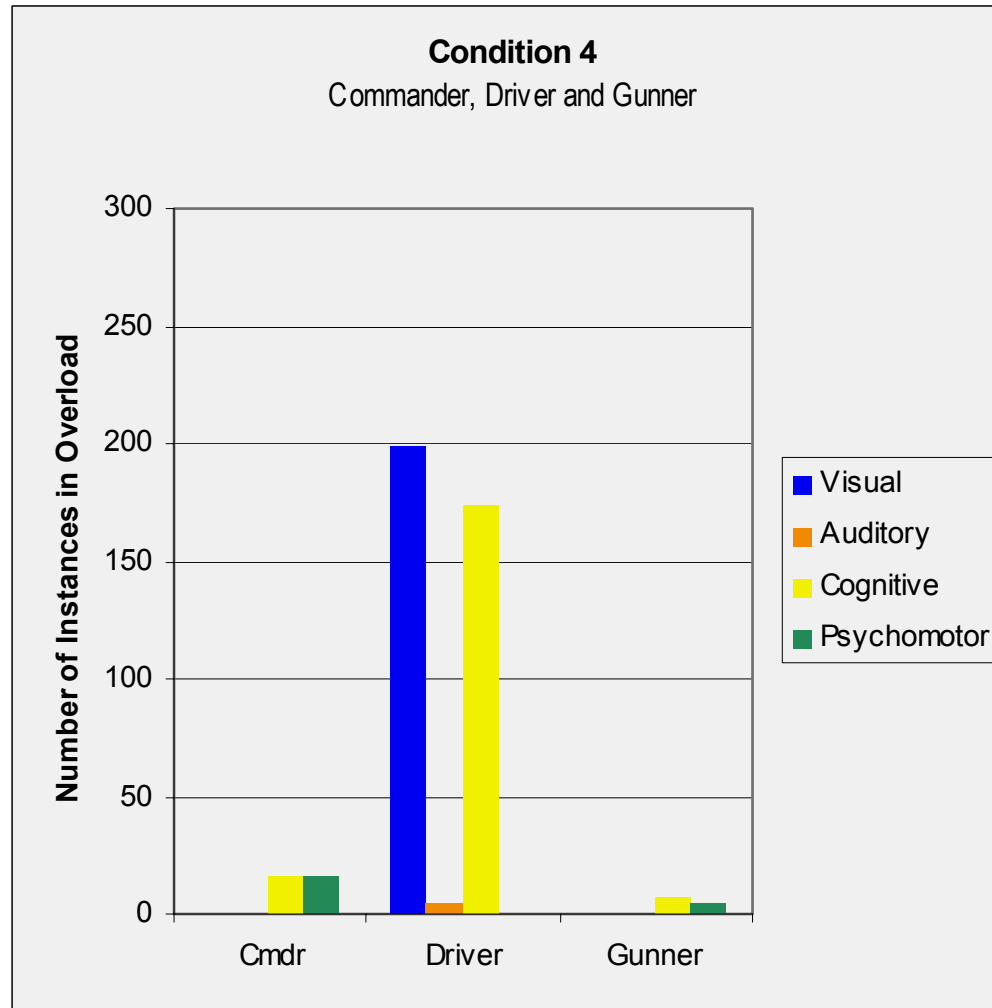
# *FCS Modeling Results*



# *FCS Modeling Results*



# FCS Modeling Results



## Commander-Driver and Gunner

		Max Value		# times >7	
		Cmdr-Driver	Gunner	Cmdr-Driver	Gunner
<b>Workload</b>	Visual	35	7	293	0
	Auditory	12	5	12	0
	Cognitive	31	9	296	2
	Psychomotor	14	9	229	5

<b>Overall Workload</b>		Cmdr-Driver	Gunner
	Max Value	86	23
	# times>40	225	0
	# times >60	61	0

## Commander-Gunner and Driver

Workload		Max Value		# times >7	
		Driver	Cmdr-Gunner	Driver	Cmdr-Gunner
	Visual	24	13	250	15
	Auditory	16	1	13	0
	Cognitive	25	16	229	20
	Psychomotor	6	16	0	21

Overall Workload		Driver	Cmdr-Gunner
	Max Value	60	39
	# times>40	41	0

## Commander, Driver and Gunner

		Max Value			# times >7		
		Driver	Commander	Gunner	Driver	Commander	Gunner
Workload	Visual	23	7	7	199	0	0
	Auditory	11	1	5	5	0	0
	Cognitive	24	17	14	173	16	7
	Psychomotor	6	15	9	0	16	5

Overall Workload		Driver	Commander	Gunner
	Max Value	56	34	33
	# times>40	28	0	0

## Gunner-Driver and Commander

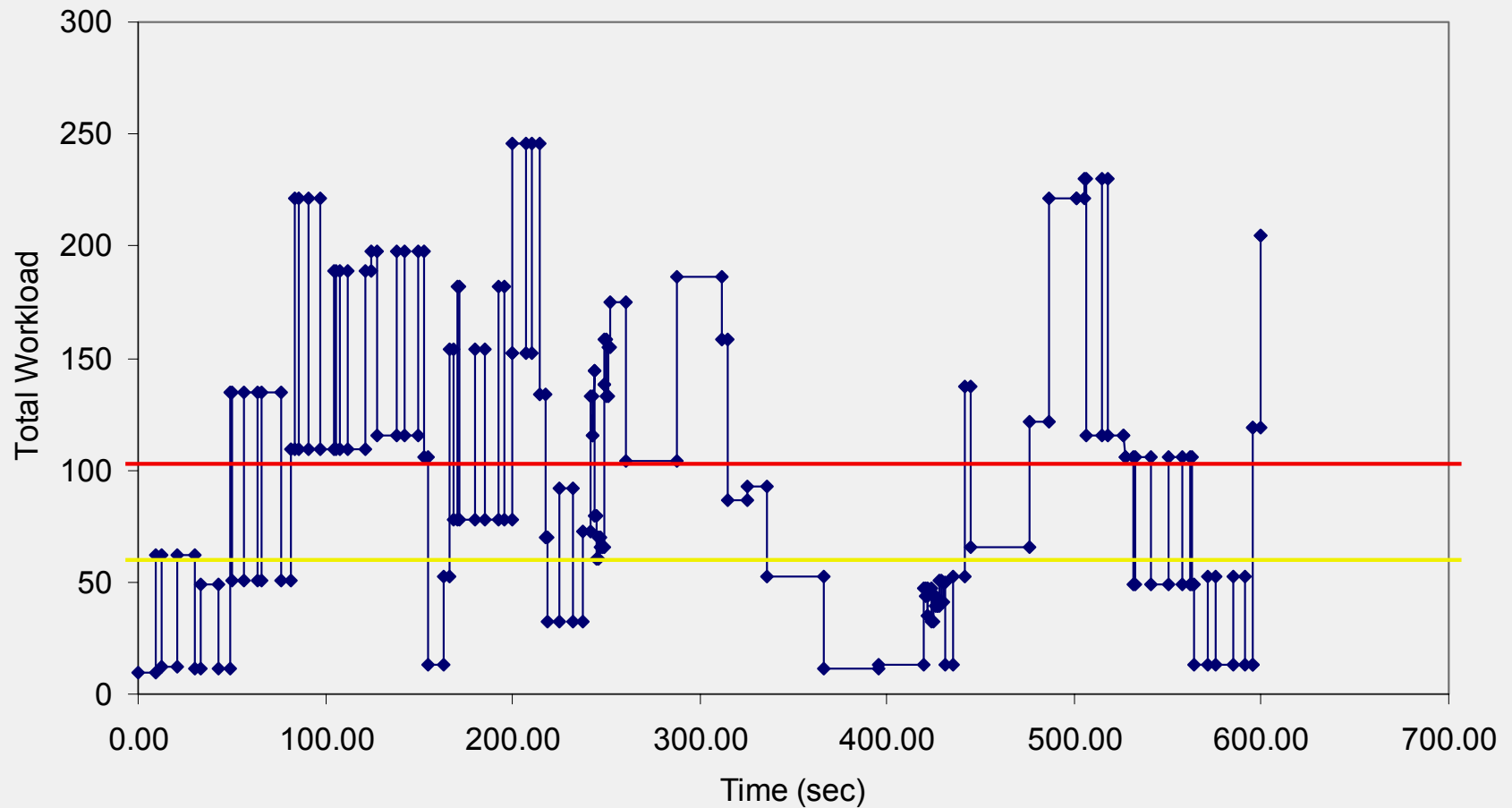
		Max Value		#times >7	
		Gunner-Driver	Commander	Gunner-Driver	Commander
Workload	Visual	25	13	256	11
	Auditory	16	1	13	0
	Cognitive	25	16	232	16
	Psychomotor	6	16	0	17

Overall Workload		Gunner-Driver	Commander
	Max Value	60	39
	# times >40	42	0



# *FCS Modeling Results CG*

Workload Over Time



# *Driving Model*

# Examining Semi-Autonomous Off Road Driving from a HIP Perspective

*Experimental Design: 3x2x2 full factorial, “within subject”*

## Independent variables:

- ◆ Operator control (direct, teleoperated, semi-autonomous)
- ◆ Obstacle frequency (low, high)
- ◆ Vehicle reliability (low, high)

## Dependent variables:

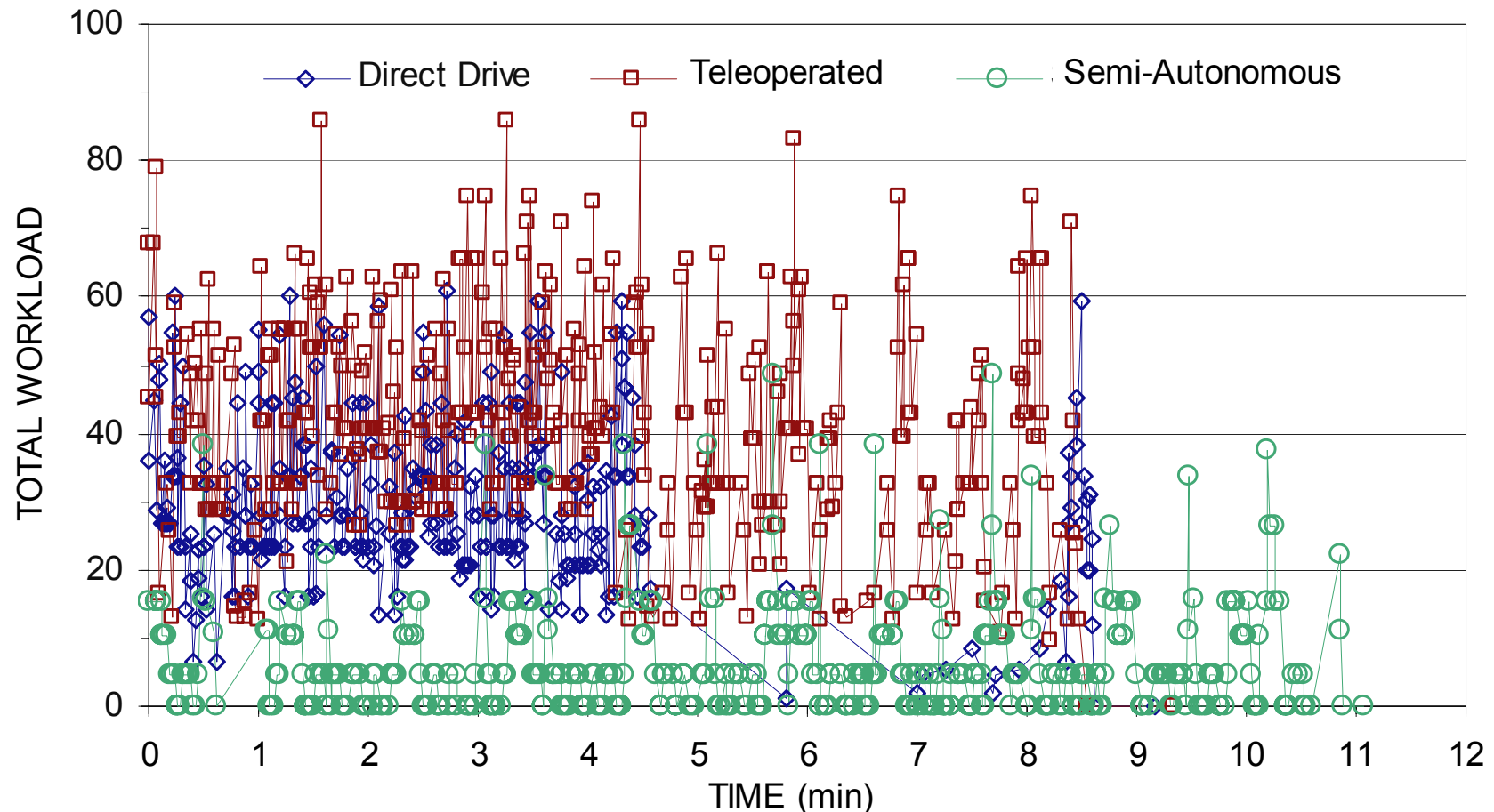
- ◆ Driver workload
- ◆ Mission completion time
- ◆ Mission completion rate

**Sample size: determined with modeling approach**



# Examining Semi-Autonomous Off Road Driving from a HIP Perspective

*Results: Workload; low obstacle; low reliability*





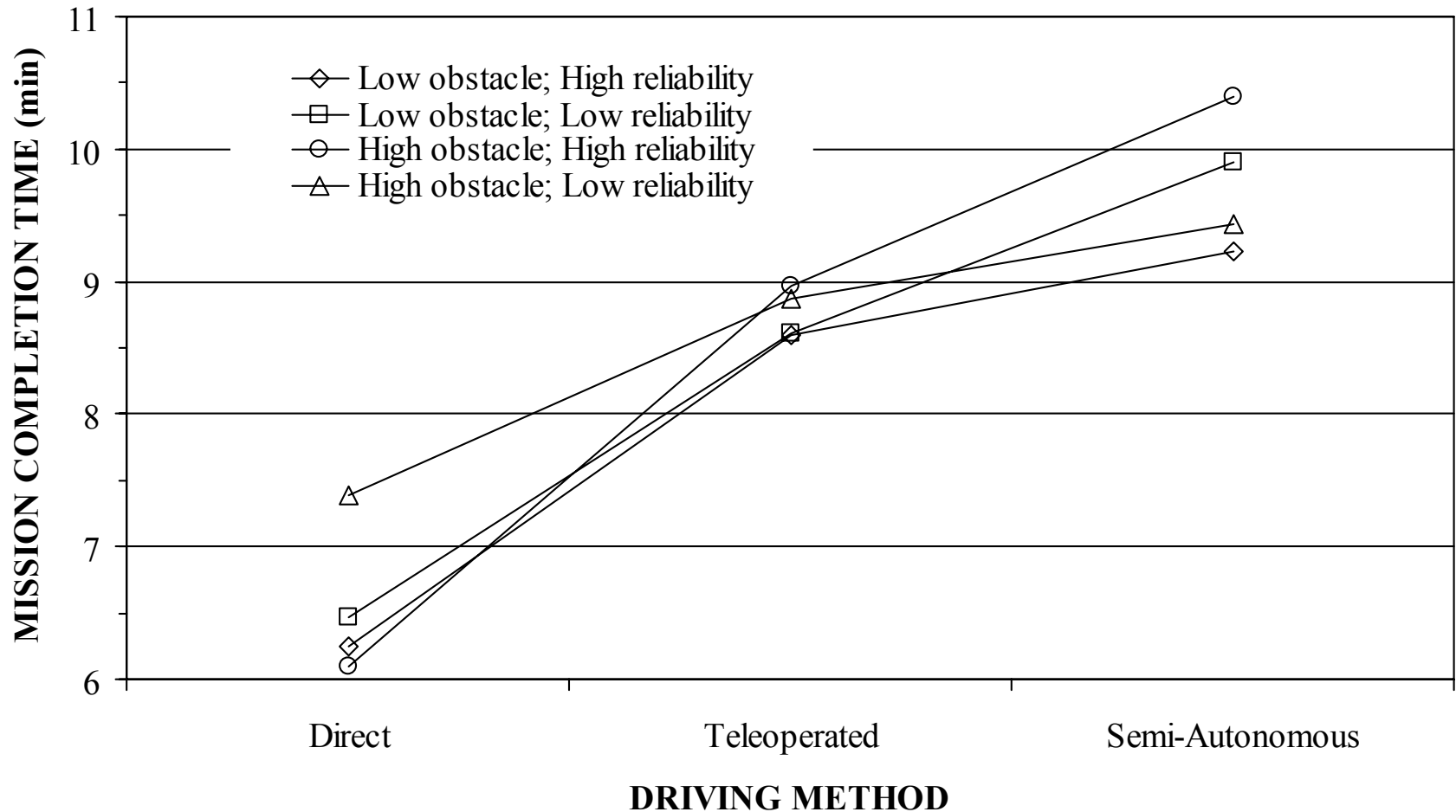
# Examining Semi-Autonomous Off Road Driving from a HIP Perspective

*Results: Direct driving workload spike*

<b>Concurrent Tasks</b>	<b>Resources</b>			
	<b>Visual</b>	<b>Auditory</b>	<b>Cognitive</b>	<b>Psychomotor</b>
Talk	0.0	4.9	4.6	1.0
Coast	0.0	1.0	0.0	0.0
Don't steer	0.0	0.0	0.0	0.0
Recognize path	5.4	0.0	1.2	0.0
Determine dist. to objective	5.0	0.0	6.8	0.0
Assess orientation	5.0	0.0	1.0	0.0
Assess traction	0.0	4.3	1.0	0.0
Assess motion	3.7	1.0	4.6	0.0
Assess function	3.7	4.3	3.7	0.0
<b>Resource Subtotal</b>	22.8	15.5	22.9	1.0
<b>Overall Resource Total</b>	62.2			

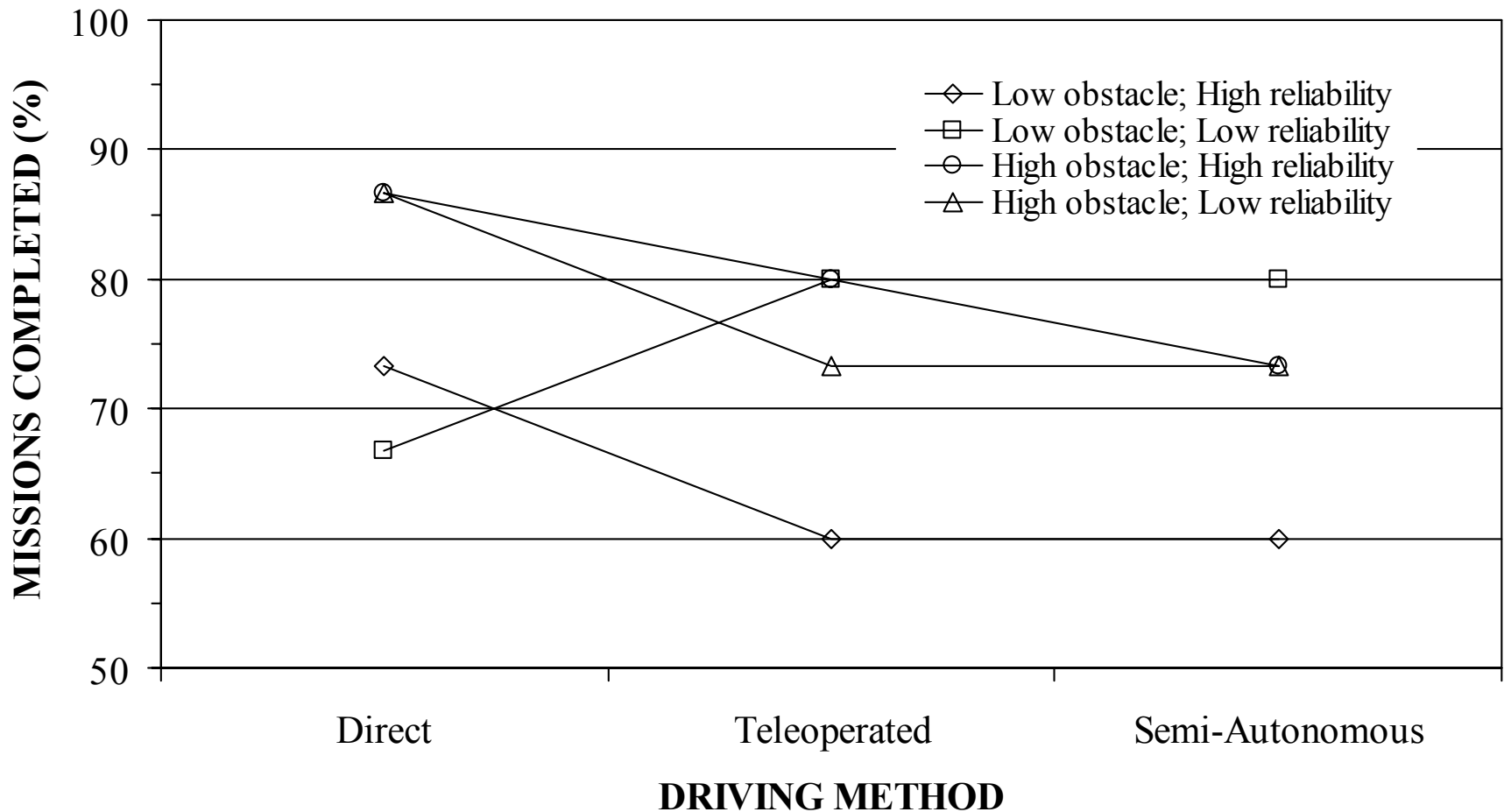
# Examining Semi-Autonomous Off Road Driving from a HIP Perspective

## Results: Mission completion time



# Examining Semi-Autonomous Off Road Driving from a HIP Perspective

## Results: Mission completion rate



# *Define Soldiers*





# *Define Soldiers Analyses*

- ◆ *Stand Alone*
- ◆ Operators in  
*Define Mission*
- ◆ Maintainers in  
*Define Equipment*



**Personnel**



**Characteristics**



# *Define Soldiers*

- ◆ Add or Delete MOSs
- ◆ Run Projection Model
  - Optional, but required to look at Personnel Reports
- ◆ Adjust Projection Model Parameters
  - Optional

# Add or Delete MOSs

- ◆ Operator, Maintainer or Supply
- ◆ “Dummy” MOS’s (for Civilians or Contractors) & Officers

Define Soldiers

MOS	End
74B	

☒ Operator  
☐ Maintainer  
☐ Supply

Use Library Data...  
 Add...  
 Delete  
 Projection...

Ok  
 Cancel  
 Help

MOS Directory

MOS Description:  
Information Systems Operator-Analyst

MOS:

- 68B
- 68D
- 68F
- 68G
- 68H
- 68J
- 68K
- 68N
- 68S
- 68X
- 68Y
- 71L
- 73C
- 73D
- 73Z
- 74B
- 74C
- 74D
- 74G

Ok  
 Cancel  
 Help

# *Performance Moderators*



# *Predicting Human Performance*

## **Define Mission**

### **Discrete event task networks**

- Performance measures
  - » Time
  - » Accuracy

## **Evaluate performance under different conditions**

### **Factors affecting human performance**

- Personnel characteristics
- Sustainment training
- Environmental stressors



# *Using Performance Moderators*

- ◆ VACP or Goal Oriented missions only
- ◆ Apply stressors via
  - individual task
  - all tasks for an MOS or crew position
- ◆ Tasks must be described via "taxons"

**Not all tasks are affected in the same way or by the same performance moderator**

*“...categories used to describe the composition of a task.”*

1. Visual Recognition/Discrimination
2. Numerical Analysis
3. Information Processing/Problem Solving
4. Fine Motor Discrete
5. Fine Motor Continuous
6. Gross Motor Light
7. Gross Motor Heavy
8. Communication – Oral
9. Communication - Read & Write

## The Nine IMPRINT Taxons, Their Descriptions, and Task Examples (Allender, Salvi et al., 1997)

Taxons	Definitions	Examples
Visual	Requires using the eyes to identify or separate targets or objects	<ul style="list-style-type: none"> <li>Seeing something move and then recognizing it as an enemy tank</li> </ul>
Numerical	Requires processing arithmetical or mathematical calculations	<ul style="list-style-type: none"> <li>Measuring an azimuth on a map with a protractor</li> <li>Estimating the distance between two points on a map</li> </ul>
Cognitive (Problem Solving and Decision)	Requires processing information mentally and reaching a conclusion	<ul style="list-style-type: none"> <li>Locating a fault in an electrical system after troubleshooting</li> <li>Selecting the best firing position for a machine gun</li> </ul>
Fine Motor Discrete	Requires performing a set of distinct actions in a predetermined sequence mainly involving movement	<ul style="list-style-type: none"> <li>Assembly and disassembly of the M-16 rifle</li> <li>Starting the engine of a truck</li> </ul>
Fine Motor Continuous	Requires expending extensive physical effort or exertion to perform an action	<ul style="list-style-type: none"> <li>Driving a vehicle</li> <li>Tracking a moving target</li> </ul>
Gross Motor Heavy	Requires expending extensive physical effort or exertion to perform an action	<ul style="list-style-type: none"> <li>Lifting an artillery round</li> <li>Loosening a very tight bolt with a wrench</li> </ul>
Gross Motor Light	Requires moving the entire body (i.e., not just the hands) to perform an action without expending	<ul style="list-style-type: none"> <li>Getting into a prone firing position</li> <li>Evacuating a tank</li> </ul>
Communication (Read and Write)	Requires either reading text or numbers that are written somewhere or writing text or numbers that can	<ul style="list-style-type: none"> <li>Reading a preventive maintenance checklist for a vehicle</li> <li>Writing a letter home</li> </ul>
Communication (Oral)	Requires either talking or listening to another person	<ul style="list-style-type: none"> <li>Giving a situation report by radio</li> <li>Receiving a password from someone while on guard duty</li> </ul>



# Assigning Taxons

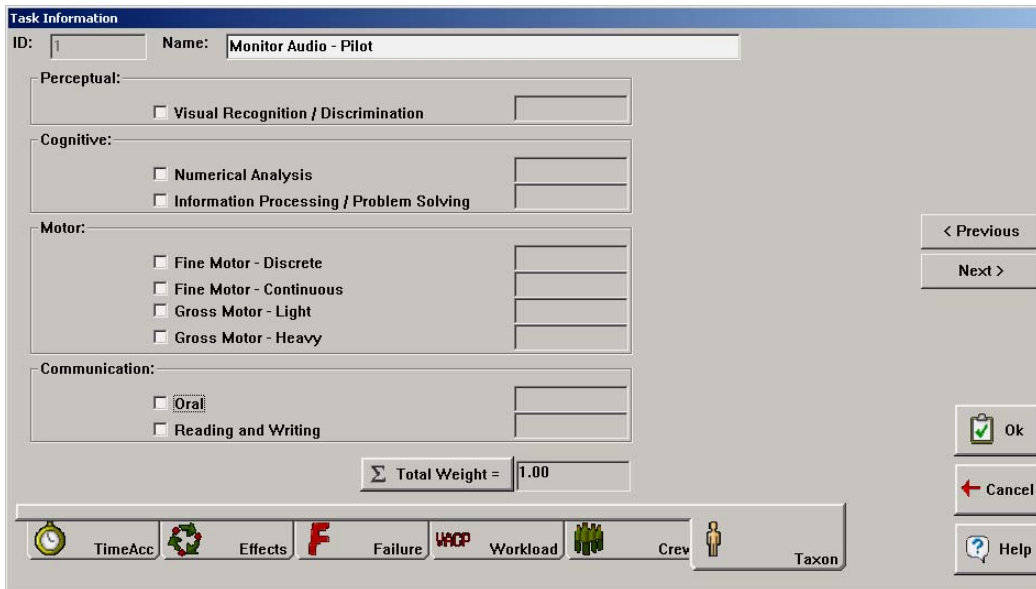
Taxons are used to calculate impact of performance moderators

## Rules

- ◆ Weightings must equal 1.0
- ◆ No more than 3 taxons per task

## Two methods

- ◆ User defines for each task
- ◆ Convert VACP workload ratings into taxon assignment



**Task Information**

ID:  Name:

**Perceptual:**

☐ Visual Recognition / Discrimination

**Cognitive:**

☐ Numerical Analysis

☐ Information Processing / Problem Solving

**Motor:**

☐ Fine Motor - Discrete

☐ Fine Motor - Continuous

☐ Gross Motor - Light

☐ Gross Motor - Heavy

**Communication:**

☐ Oral

☐ Reading and Writing

$\Sigma$  Total Weight =

< Previous

Next >

Ok

Cancel

Help

TimeAcc Effects Failure VACP Workload Crew Taxon



# *Performance Shaping Functions*

## ◆ Used Project A database - ARI

- ◆ 1985 data
- ◆ 9,500 soldiers total
- ◆ 9 different military occupational specialties
- ◆ full data set on 9-MOS sample = 5,000 soldiers
- ◆ updated in 1997 with longitudinal data

11B - Infantryman  
13B - Cannon Crewman  
19E - Tank Crewman  
31C - Radio Teletype Op  
63B - Veh & Gen. Mech Spc.  
71L - Admin Spec  
91A - Med Care Spec  
88M - Motor Transport Operator  
95B - Military Police

- ◆ Derived algorithms describing relationship of MOS personnel characteristics and training frequency & recency with task performance by task type
- ◆ Provided "what if" options in IMPRINT



# Personnel Characteristics

**ASVAB\***  
**Composite**  
CL-ST  
.....  
**Test Score**  
**Category Cutoff**  
0 - 135  
.....  
**Test Score**  
**Category**  
II - IV

Assign Personnel Characteristics

MOS and Job:  
11B Driver

Mission:  
Fly from Landing Zone (LZ) to Pickup Zone

Function:  
All

Tasks:  
All

Personnel Characteristics

ASVAB Composite:  
CO

CutOff:  
90

Test Score Category:  
IIIB

Review...

Apply

Ok

Cancel

Help

Personnel Characteristics Training Frequency Stressors

\*Armed Services Vocational Aptitude Battery



# Impact of Personnel Characteristics

(currently modeled in IMPRIINT)

Taxons	Increase/decrease of ASVAB affects:
Visual	A
Numerical Analysis	T/A
Information Processing	T/A
Fine Motor - Discrete	T/A
Fine Motor - Continuous	
Gross Motor - Light	A
Gross Motor - Heavy	
Commo (Reading & Writing)	T/A
Commo (Oral)	A

T = affects task time, A = affects task accuracy, TA= affects both

# Sustainment Training

## Training Frequency

Less than twice a year – once a week or more

**Assign Training Frequency**

MOS and Job:

Mission:

Function:

Tasks:

Training Frequency

Personnel Characteristics  Stressors

<b>Taxons</b>	<b>Less than twice a year</b>	<b>Less than once a month</b>	<b>Once a month (default)</b>	<b>2 or 3 times a month</b>	<b>Once or more a week</b>
Visual					
Numerical Analysis	T/A	T/A	T/A	T/A	T/A
Information Processing					
Fine Motor - Discrete	A	A	A	A	A
Fine Motor - Continuous					
Gross Motor - Light					
Gross Motor - Heavy					
Commo (Reading & Writing)	T/A	T/A	T/A	T/A	T/A
Commo (Oral)					

T = affects task time, A = affects task accuracy, TA= affects both

# Environmental Stressors Screen

### Assign Stressors

**MOS and Job:**

11B Driver

**Mission:**

Fly from Landing Zone (LZ) to Pickup Zone

**Function:**

All

**Tasks:**

All

**Cold**

Temperature:

N/A

Wind (knots):

N/A

**Heat**

Temperature:

N/A

Humidity (%):

N/A

☐ Fahrenheit

☒ Celsius

Review...

Apply

**Noise**

Distance(feet):

N/A

Decibels:

N/A

**MOPP Level**




N/A




**Sleepless Hours**

N/A

**User Defined Stressors**

Name	Level

 Personnel Characteristics
  Training Frequency
  Stressors

 Ok
  Cancel
  Help



# *Environmental Stressors*

<b>Heat</b>	measured by	<b>Temperature &amp; Humidity</b>
<b>Cold</b>	measured by	<b>Temperature &amp; Wind speed</b>
<b>Noise</b>	measured by	<b>Distance &amp; Noise level (dbs)</b>
<b>MOPP</b>	measured by	<b>Level (0 - 4)</b>
<b>Sleepless Hours</b>	measured by	<b>Hours since last slept</b>

**When stressors are applied to tasks,  
either accuracy, time, both or neither are affected**



<b>Taxon</b>	<b>MOPP</b>	<b>Heat</b>	<b>Cold</b>	<b>Noise</b>	<b>Sleepless Hours</b>
Visual	T	A	T		
Numerical		A			TA
Cognitive		A			TA
Fine Motor Discrete	T	A	T		
Fine Motor Continuous					
Gross Motor Light	T		T		
Gross Motor Heavy					
Commo. (Read & Write)		A			
Commo. (Oral)	T	A		A	

T = affects task time, A = affects task accuracy, TA= affects both

**Not all tasks are affected in the same way or by the same stressor**

## IMPRINT Environmental Stressors and the Taxon Types Affected by Either Time or Accuracy or Both (adapted from Micro Analysis & Design and Allender, Salvi et al., 1997)

<b>Taxons</b>	<b>MOPP</b>	<b>Heat</b>	<b>Cold</b>	<b>Noise</b>	<b>Sleepless Hours</b>
Visual	T	A	T	NO DATA	A
Numerical	NO DATA	A	<b>NO EFFECT</b>	NO DATA	TA
Cognitive (Problem Solving and Decision Making)	NO DATA	A	<b>NO EFFECT</b>	NO DATA	TA
Fine Motor Discrete	T	A	T	NO DATA	NO DATA
Fine Motor Continuous	NO DATA	NO DATA	NO DATA	NO DATA	T
Gross Motor Light	T	NO DATA	<b>T - CONFLICT</b>	NO DATA	<b>NO EFFECT</b>
Gross Motor Heavy	NO DATA	NO DATA	NO DATA	NO DATA	<b>NO EFFECT</b>
Communication (Read and Write)	NO DATA	A	NO DATA	NO DATA	NO DATA
Communication (Oral)	T	A	NO DATA	A	NO DATA

T = Affects task time A = Affects task accuracy TA = Affects both NO DATA = No research identified for input T – CONFLICT = current data shows a conflict with current IMPRINT degradation and the literature Items in bold are new stressor degradations not currently in IMPRINT



# *Stressor Update in Process...*

- ◆ Hours since last sleep
  - IMPRINT too optimistic! Impact at < 24 hours
  - Does affect all taxons
- ◆ Circadian rhythm
  - Important stressor including interaction w/ sleep loss
  - Need time of day interface
- ◆ Nuclear, biological, & chemical
  - Exposure effects, type & time; need to map to IMPRINT taxons
- ◆ Vibration
  - Dimensions of vibration
- ◆ Noise
  - Does affect cognitive tasks
- ◆ Some empty cells in IMPRINT matrix are OK

# Combining Stressors

$$DF_T = \prod_{i=1,n} \sqrt[n]{DF_i}$$



Power Function

Where:

$DF_T$  = Total degradation factor

$DF_i$  = The  $i^{\text{th}}$  degradation factor when  
when ordered from largest effect to  
smallest effect

$n$  = Number of degradation factors

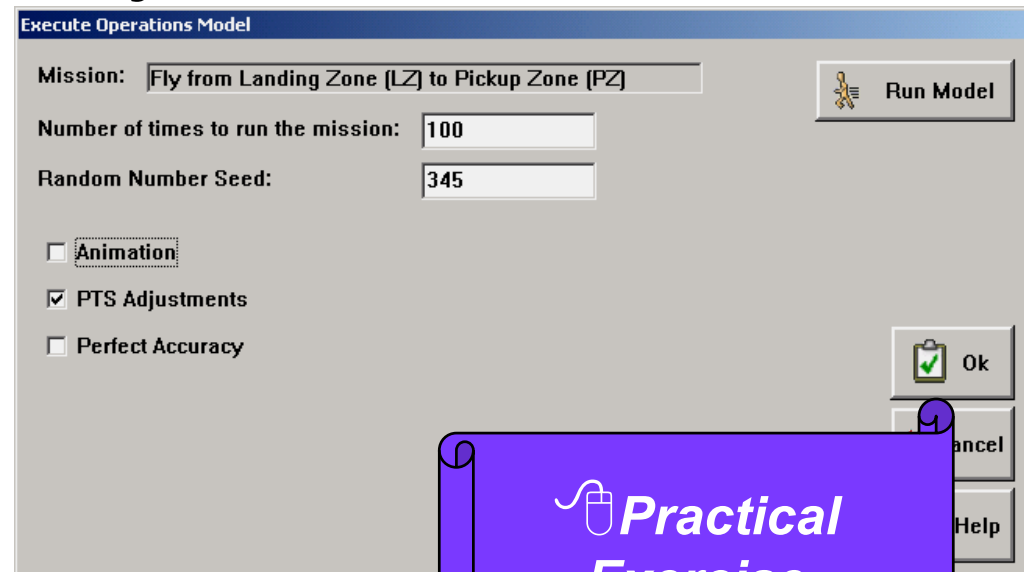


# *Applying All PTS Options*

- ◆ First apply ***Personnel Characteristics***
- ◆ Then apply ***Training Frequency***
- ◆ Apply ***Stressors*** last

# *Running the Model with PTS Options*

- ◆ Run baseline model first
- ◆ Apply PT and/or S
- ◆ Review effects by task
- ◆ Re-run model with Adjustments selected
- ◆ Compare outputs with baseline



 **Practical  
Exercise**

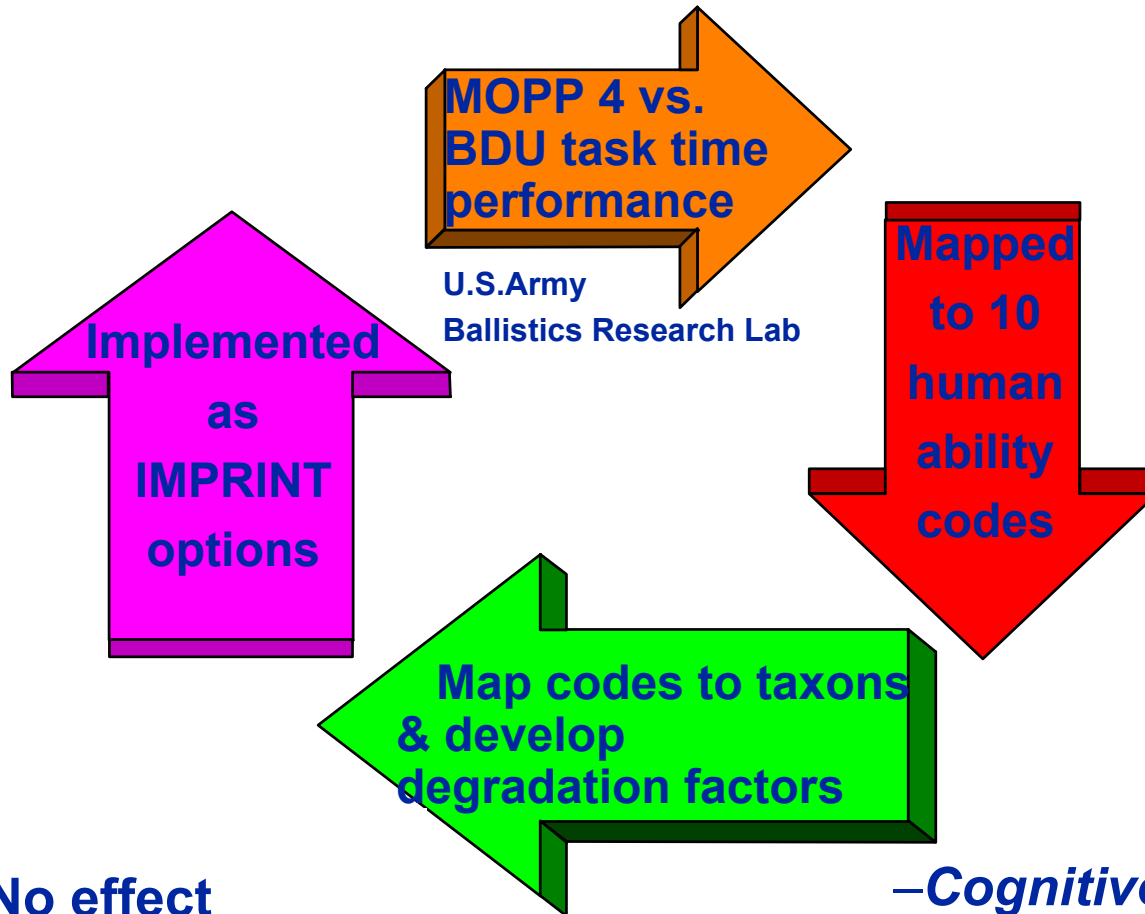
# Workload to Taxons

<b>Mental Workload Ratings</b>	<b>Taxons</b>
<i>Visual</i> 1.0, 3.7, 4.0, 5.0, 5.4, 7.0	Visual
<i>Cognitive</i> 7.0	Numerical Analysis
<i>Cognitive</i> 1.0, 1.2, 3.7, 4.6, 5.3, 6.8	Information Processing
<i>Psychomotor</i> 2.2, 4.6, 5.8, 7.0	Fine Motor - Discrete
<i>Psychomotor</i> 2.6	Fine Motor - Continuous
---	Gross Motor - Light
---	Gross Motor - Heavy
<i>Auditory</i> 4.9, 6.6, 7.0	Commo (Reading & Writing)
<i>Psychomotor</i> 1.0	
<i>Visual</i> 5.9	Commo (Oral)
<i>Psychomotor</i> 6.5	
<i>Auditory</i> 1.0, 2.0, 4.2, 4.3	---

**Note: VACP workload scores do not map to Gross Motor taxons because workload channels are mental not physical workload**



# Development of MOPP Degradation Factors



MOPP 0 = No effect

...

–MOPP 4 = Up to 1.7 X as long

–Cognitive degradation?

–Accuracy degradation?

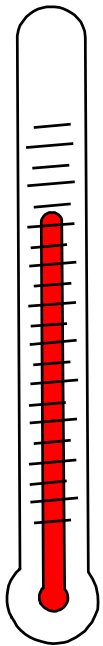
–Work rate parameter?



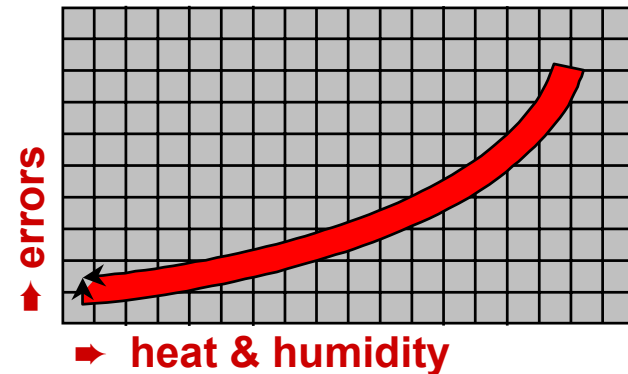


# Development of Heat Degradation Factors

- ◆ Heat degradation factors in IMPRINT derived from studies relating heat stress to inaccurate performance



- » Bioastronautics Data Book, 1981
- » Parker, 1973
- » MIL-HDBK-759A



- *Additional parameters (work rate, clothing, etc.)?*

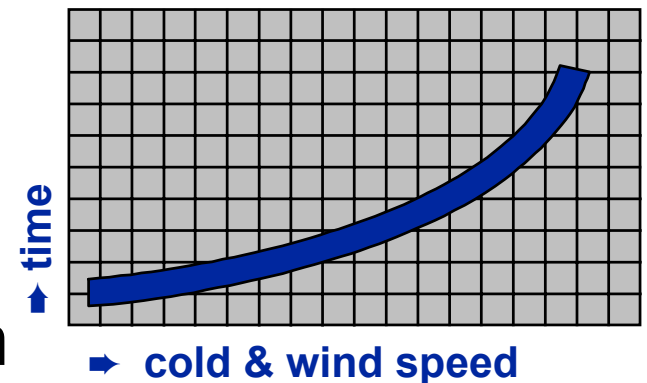
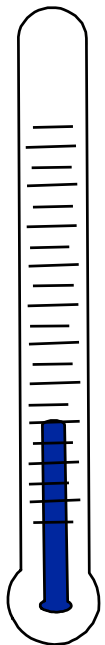
# Development of Cold Degradation Factors

## ◆ Cold degrades task time as a function of ambient temperature and wind velocity

- Derived from Teichner (1958) relating wind chill to % performance loss

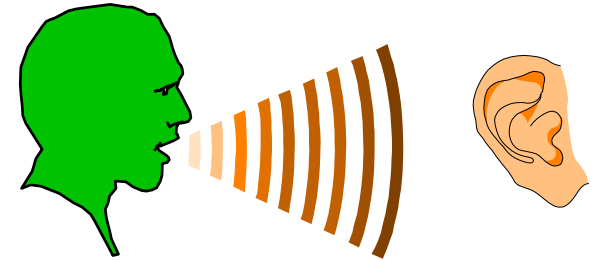
- » One for visual reaction time & fine motor discrete
- » Another for gross motor light

- Assumes bare skin
- Assumes linear degradation across decreasing temperatures



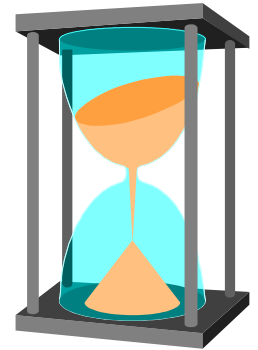
# *Development of Noise Degradation Factors*

- ◆ Noise degrades task accuracy as a function of noise level & speaker-listener distance
  - Derived from Human Engineering Design Criteria MIL-STD-1472C
  - Need to consider communication frequency & voice level



# *Development of Sleepless Hours Degradation Factors*

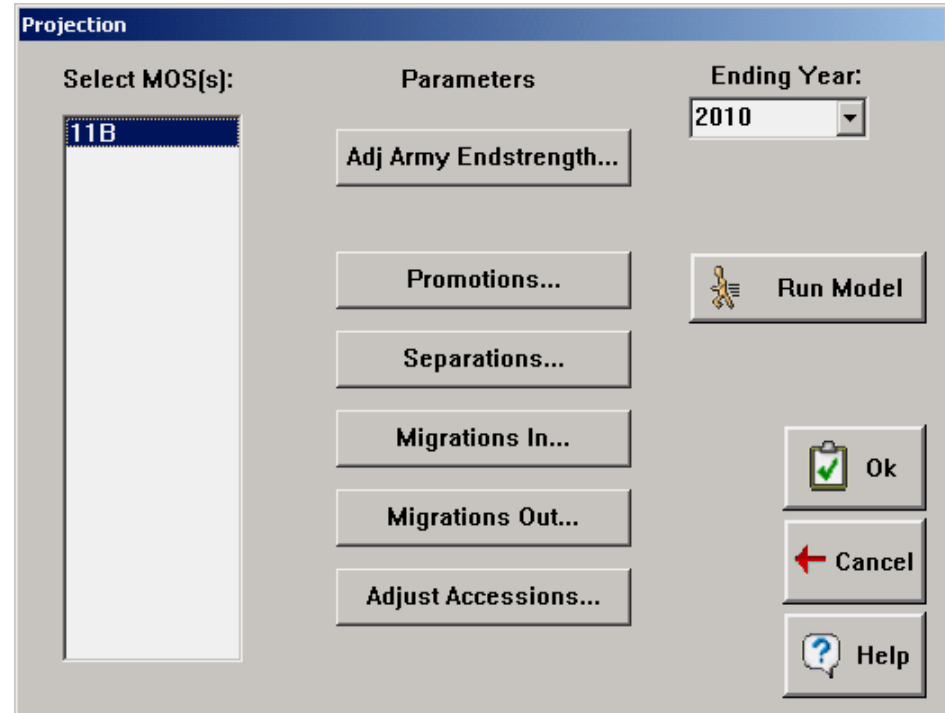
- ◆ Hours since last sleep degrades time & accuracy
  - Derived from a review of several studies
  - Cognitive performance is more sensitive to degradation than physical strength and endurance tasks
  - Decline in performance is roughly 25% for every 24 hours of operation
  - *Need degradation for non-cognitive work*



# *Projection Model*

# Projection Model Data

- ◆ Current inventory
- ◆ Promotion rates
- ◆ Separation rates
- ◆ Migration in & out rates
- ◆ Historical accessions

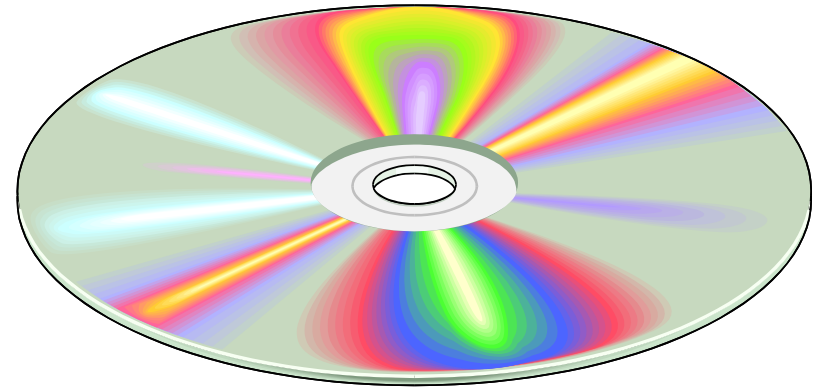


The screenshot shows a software window titled "Projection". It contains several input fields and buttons. On the left, under "Select MOS(s):", there is a list box with "11B" selected. To the right, under "Parameters", there are five buttons: "Adj Army Endstrength...", "Promotions...", "Separations...", "Migrations In...", and "Migrations Out...". Further right, under "Ending Year:", there is a dropdown menu showing "2010". At the bottom right, there are three buttons: "Run Model" (with a person icon), "Ok" (with a checkmark icon), and "Cancel" (with a red arrow icon). A "Help" button (with a question mark icon) is also present at the bottom right.

# *Use Army Library Data*

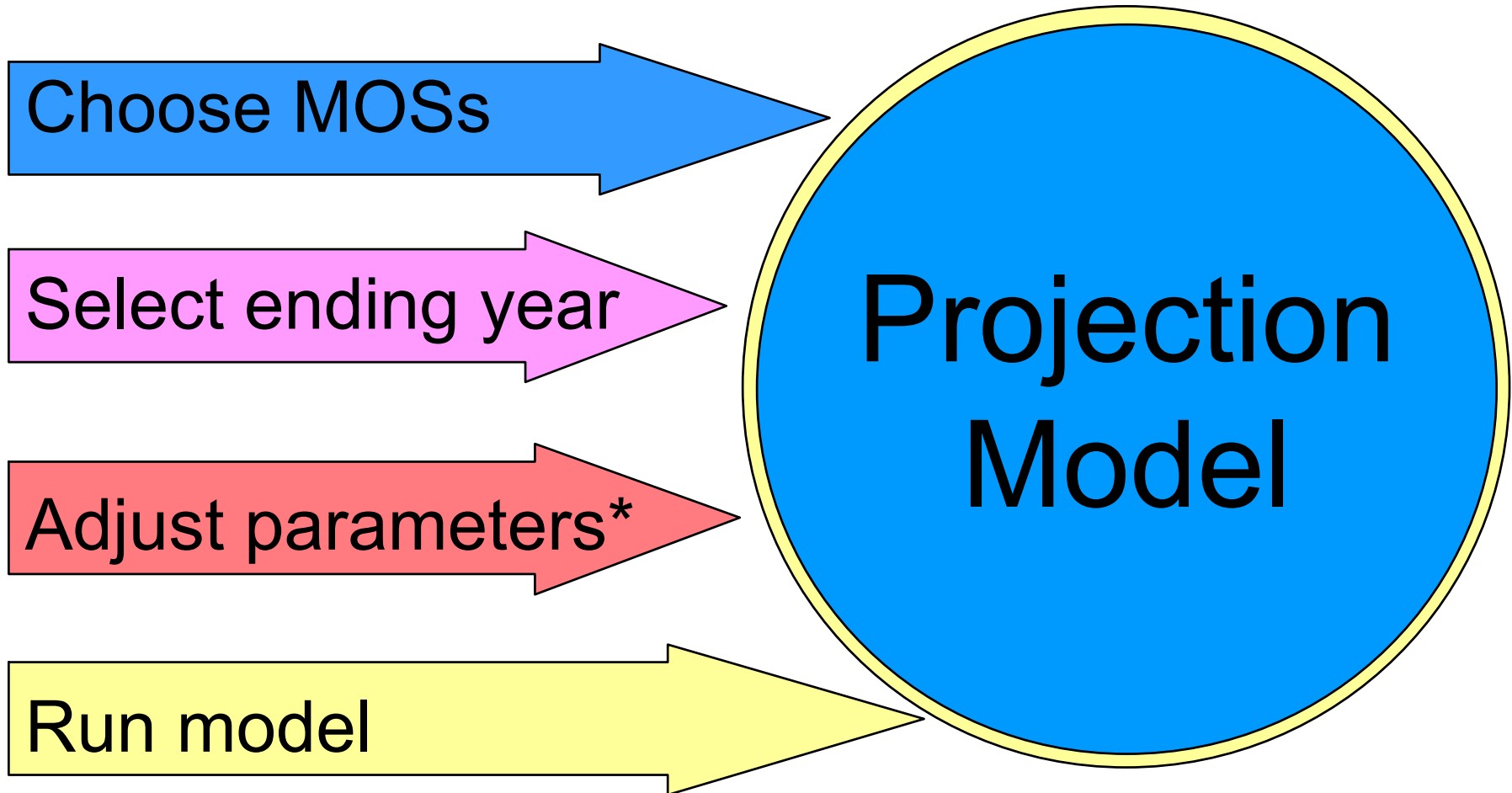
- ◆ MOS data for 22 historical systems
- ◆ Operators and maintainers
- ◆ Associated personnel characteristic data

**MARC Maint.  
Database**



**Enlisted Master  
File**

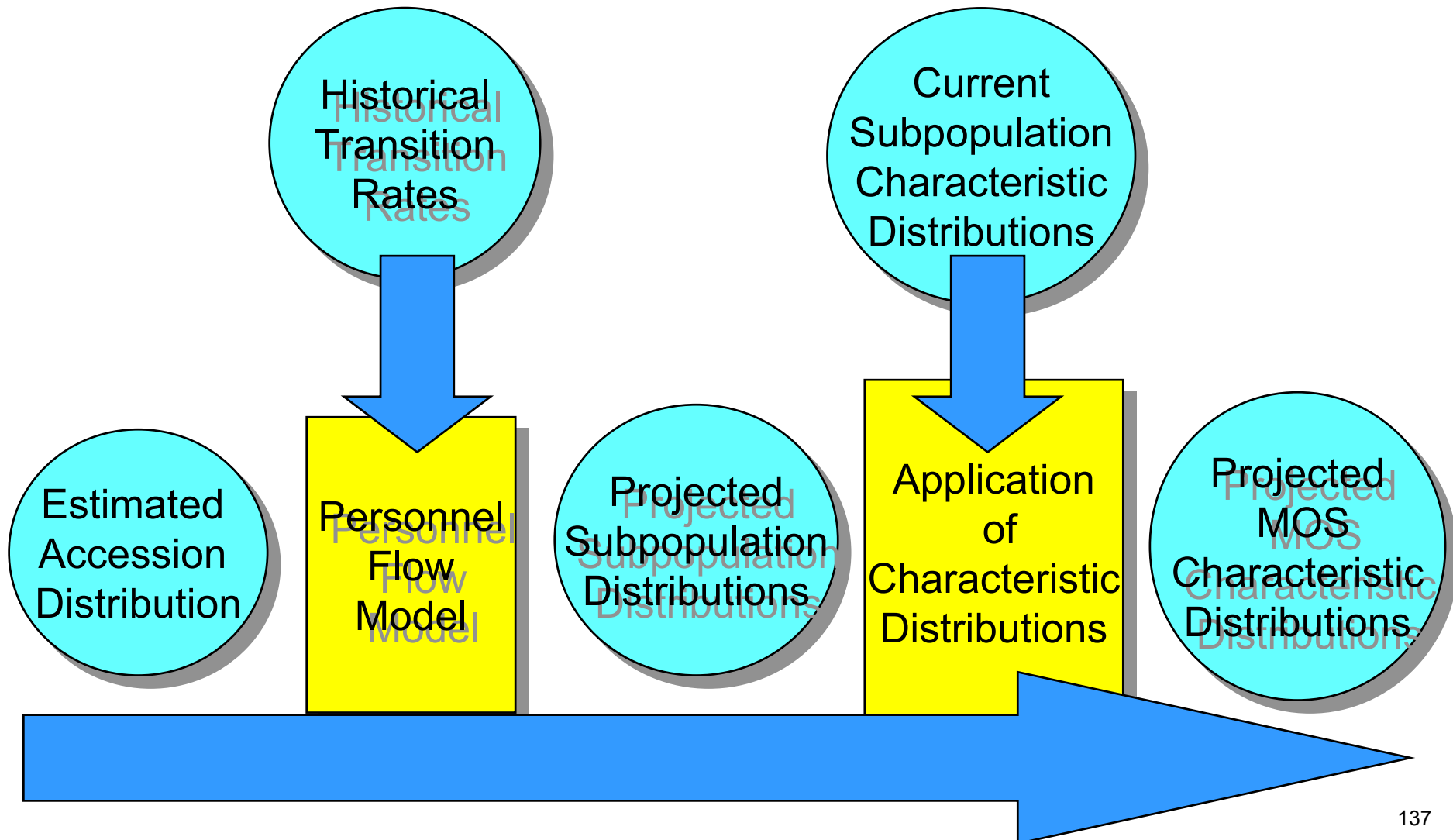
# *Run Projection Model*



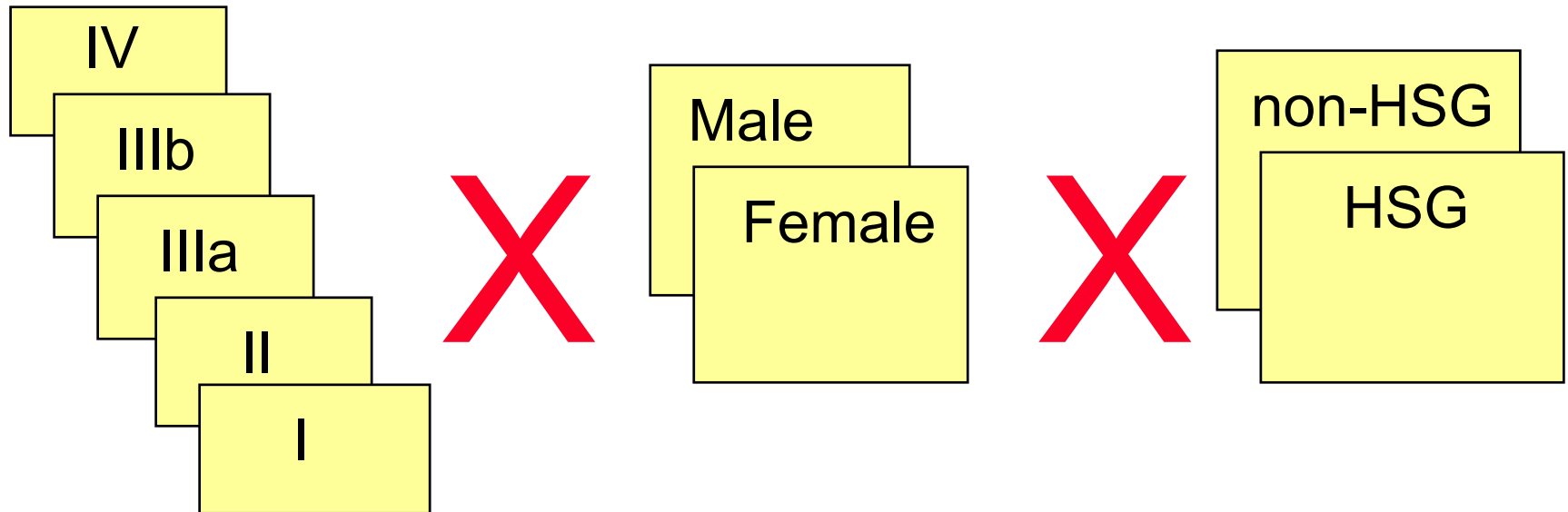
\* optional step



# Projection Model



By MOS and Grade



★ Each subpopulation is flowed separately ★

# Define Soldiers Reports

**Projection Report Criteria**

MOS:  
**11B**

Test Score Cat

- ☒ I
- ☒ II
- ☒ IIIa
- ☒ IIIb
- ☒ IV

Gender

- ☒ Male
- ☒ Female

Reported  
2010

Printer Setup...

Report...

Education

- ☒ High School Graduate
- ☒ Non-High School Graduate

Ok

Cancel

Help

# Define Soldiers Reports (cont)

**Personnel Characteristics Report Criteria**

MOS:  
**11B**

Test Score Cat

- ☒ I
- ☒ II
- ☒ IIIa
- ☒ IIIb
- ☒ IV

Gender

- ☒ Male
- ☒ Female

Reported  
2010

Printer Setup...

Education

- ☒ High School Graduate
- ☒ Non-High School Graduate

Print Report

- Read Grade Level
- Weight Lift
- PULHES (Eyes)
- ASVAB

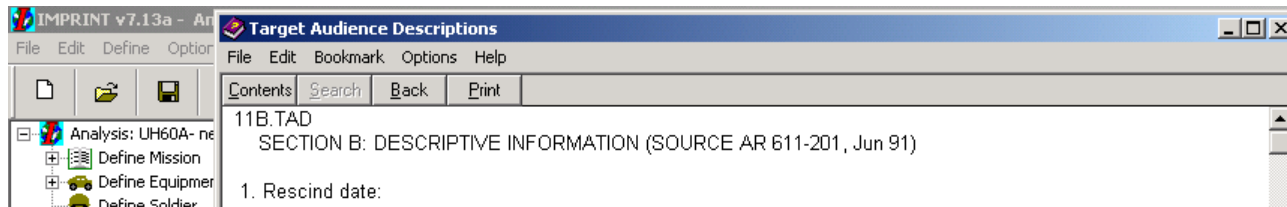
Ok

Cancel

Help



# Target Audience Description Info



**Go to DA PAM 611-21 at:**

**[http://www.usapa.army.mil/USAPA\\_PUB\\_search\\_P.asp](http://www.usapa.army.mil/USAPA_PUB_search_P.asp)**

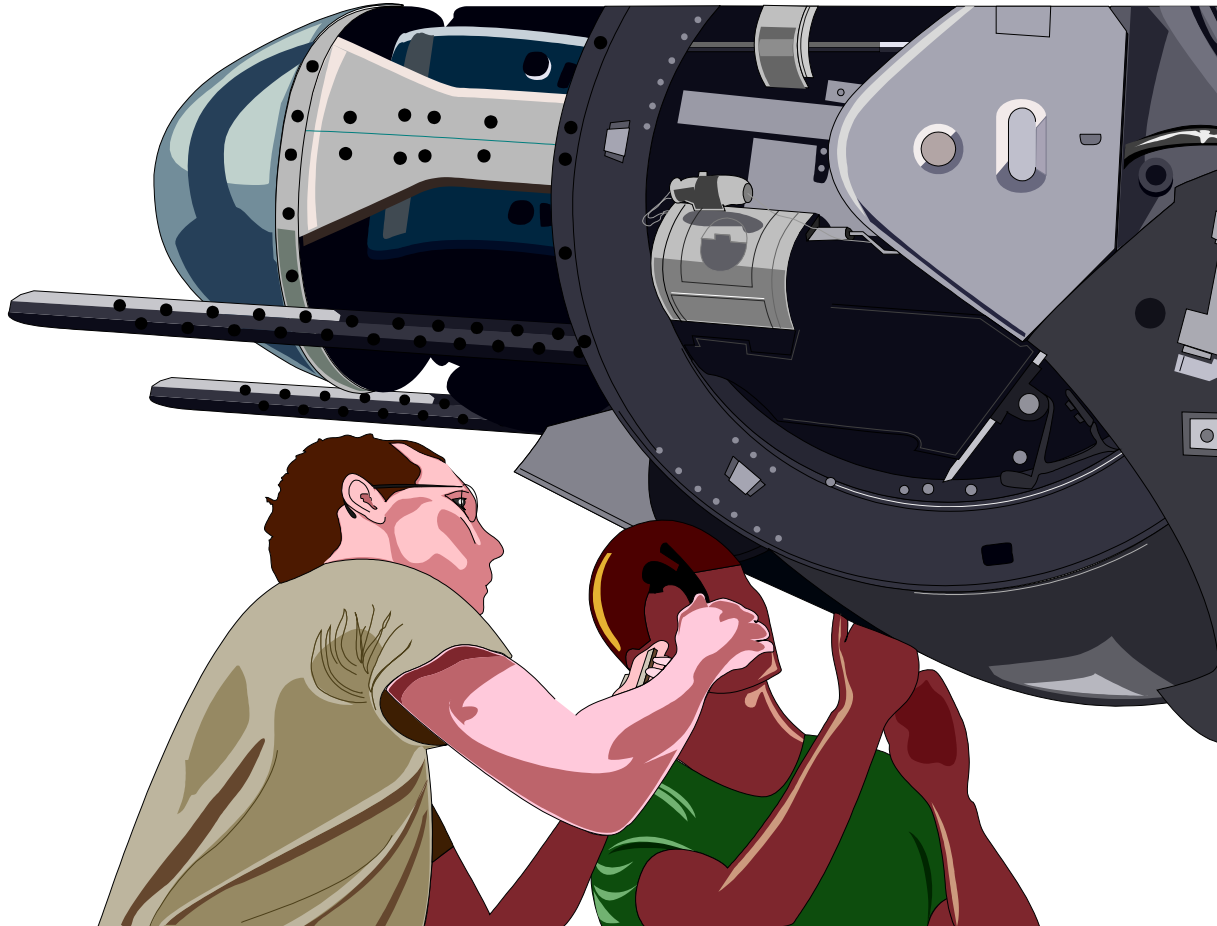
**Or**

**[https://www.arl.army.mil/ARL-Directorates/HRED/imb/imprint/p611\\_21.pdf](https://www.arl.army.mil/ARL-Directorates/HRED/imb/imprint/p611_21.pdf)**

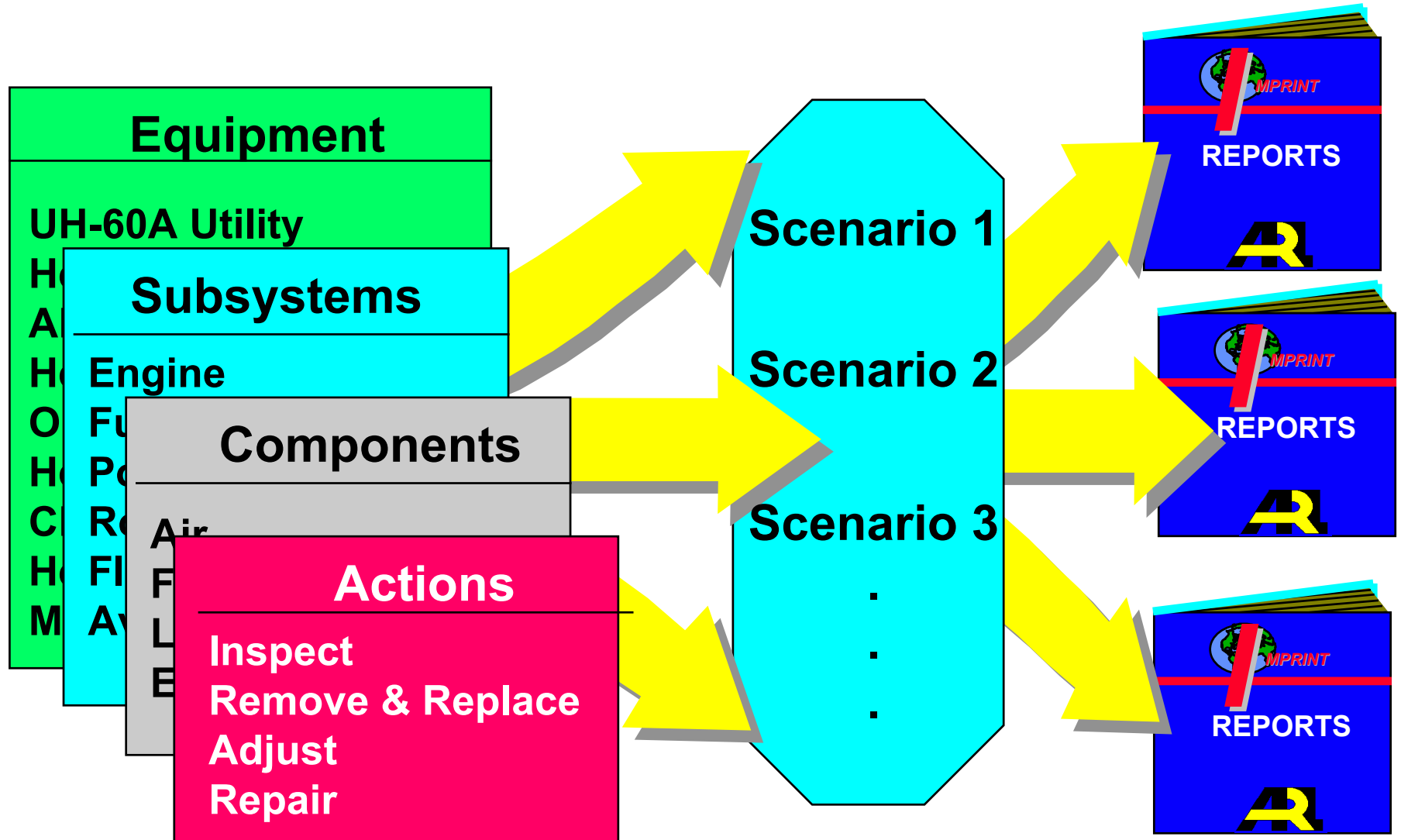
Skill Level	Tasks
10	Performs preventive maintenance and assists in organizational maintenance on weapons and equipment.
10	Protects self, weapons and equipment from chemical and other contaminants.
10	Carries and prepares ammunition for use and loads weapons.
10	Administers first aid.
10	Applies field sanitation methods.
10	Ensures highest state of physical readiness at all times.

 **Practical  
Exercise**

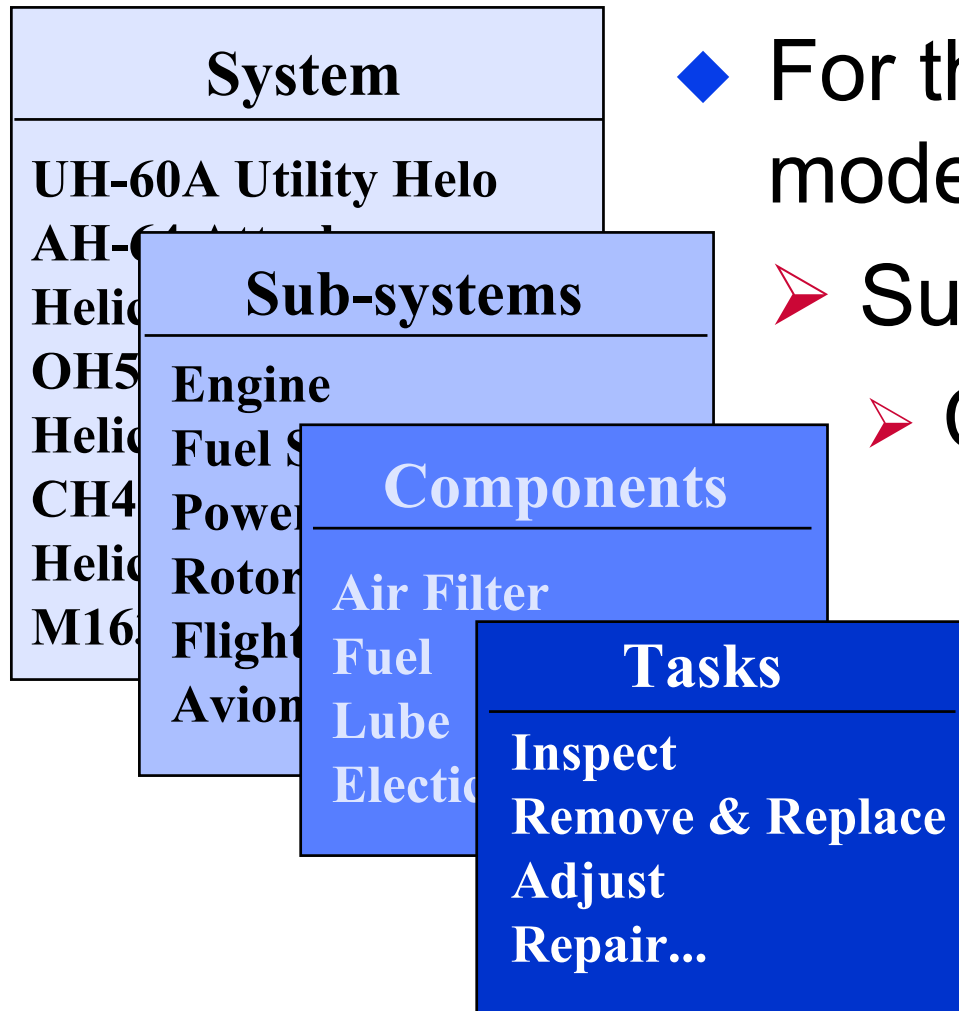
# *Define Equipment*



# Define Equipment Process



# System-to-Task Decomposition



◆ For the system being modeled, identify

➤ Sub-systems

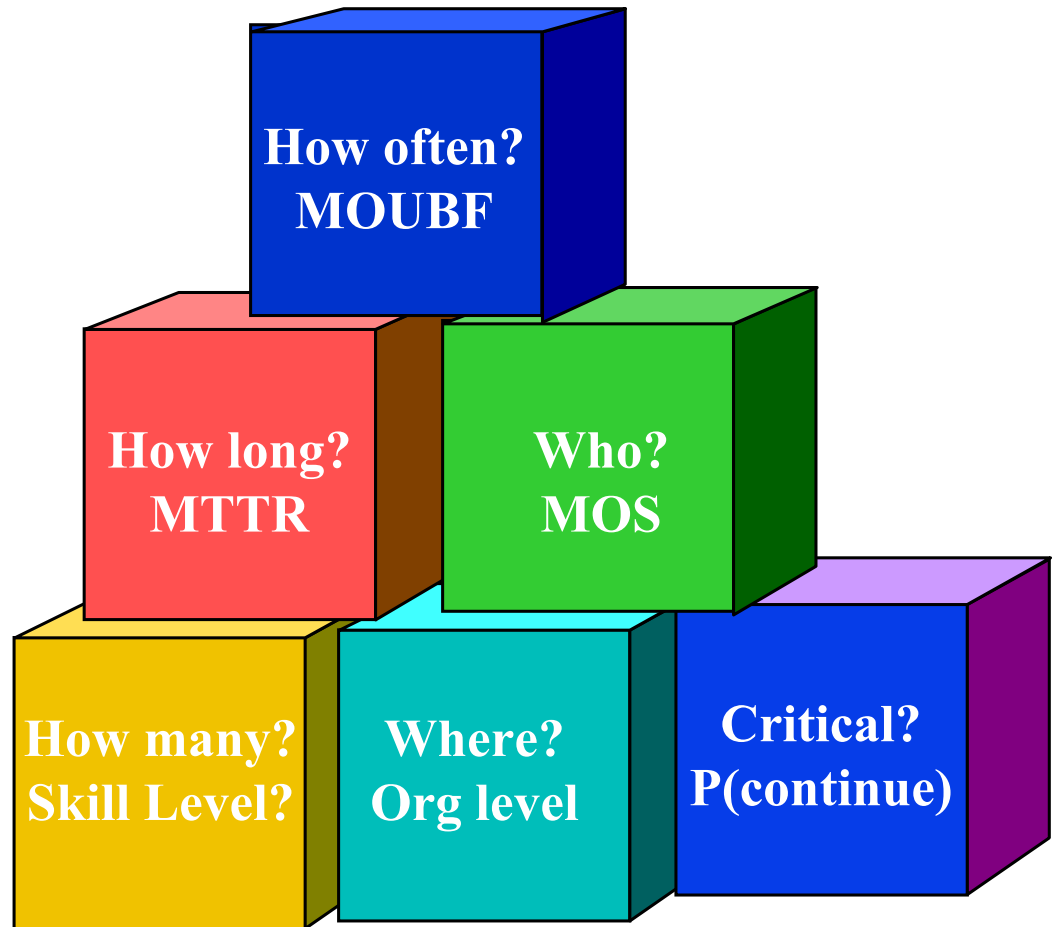
➤ Components

➤ Tasks which are either corrective or preventive



# *Maintenance Task Data*

- ◆ Mean operational unit between failure (i.e., maintenance actions)
- ◆ Mean time to repair
- ◆ Soldier job specialty
- ◆ How many of what skill level
- ◆ Organizational level
- ◆ Mission criticality



- ◆ System Operational Profile
- ◆ Maintenance Crew
  - Number & types of people available to do the maintenance on each shift
- ◆ Travel Time
  - Amount of time to get system to the people (or people to the system) on the battlefield
- ◆ Repair Parts
  - Likelihood a part is available
  - Average wait time, if not available



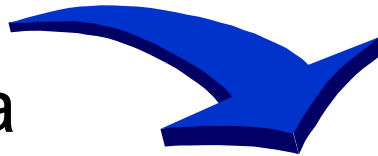
# *Operational Profile Data Items for Every Segment*

◆ Consumables (i.e.,  
Usage) data

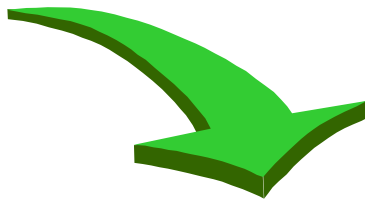


**Distance traveled  
Rounds fired  
Load Time**

◆ Time & systems data



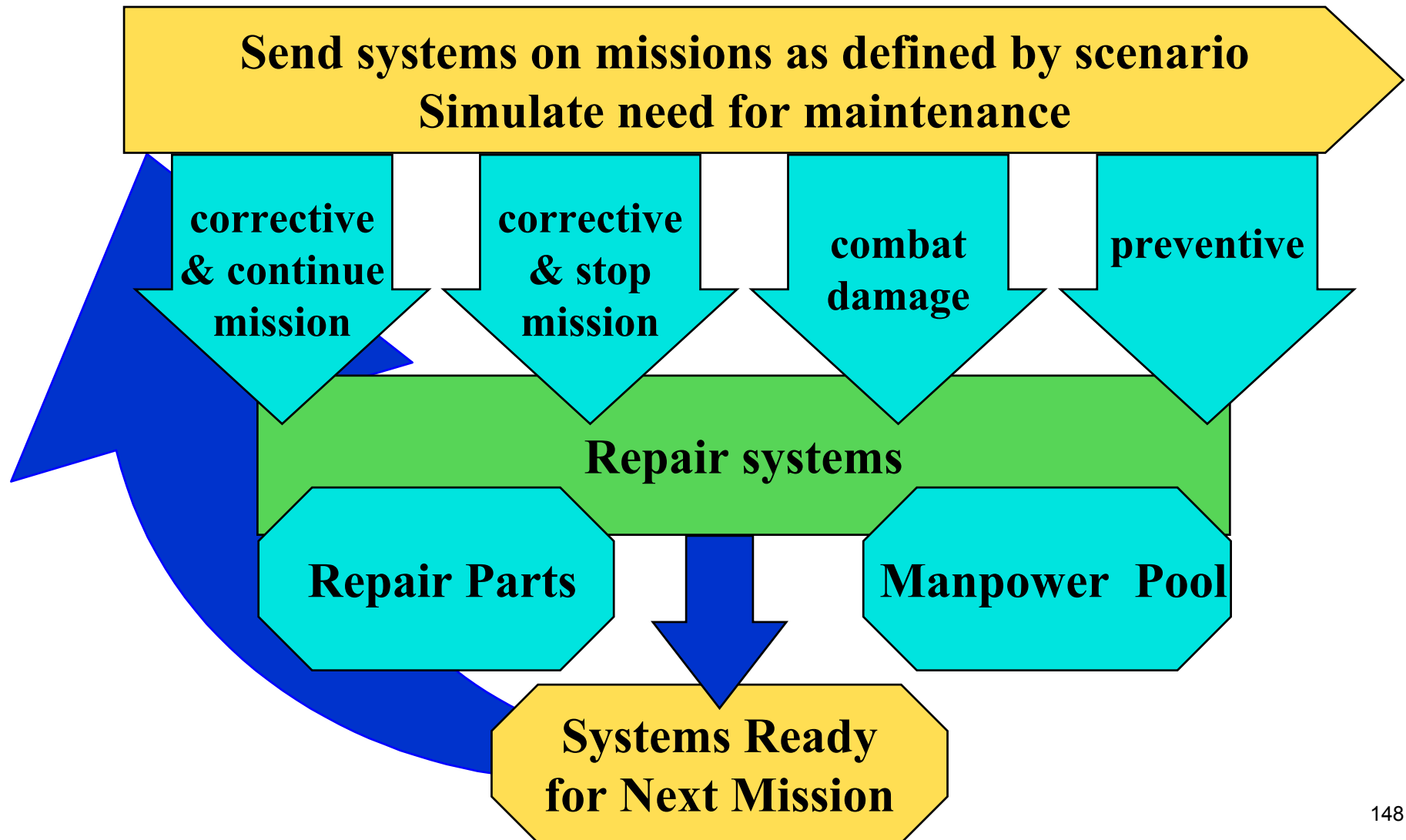
◆ Combat data



**Probability of hit  
Probability of kill  
Replacement time**

**Start time & day  
Duration  
Priority  
Max and min # systems needed  
Number of systems per mission**

# *Stochastic Maintenance Model*



# Maintenance Model Reports

## Detailed & Summary Measures

- ◆ Maintenance manhours by:
  - task, component, & sub-system
  - preventive & corrective maintenance
  - organizational level
  - soldier job specialty
- ◆ Achieved operational availability & readiness
- ◆ Maintenance to operational hours ratio
- ◆ High driver subsystems
- ◆ Personnel utilization
- ◆ Logistics downtime
- ◆ Combat damage
- ◆ ...



 **Practical  
Exercise**

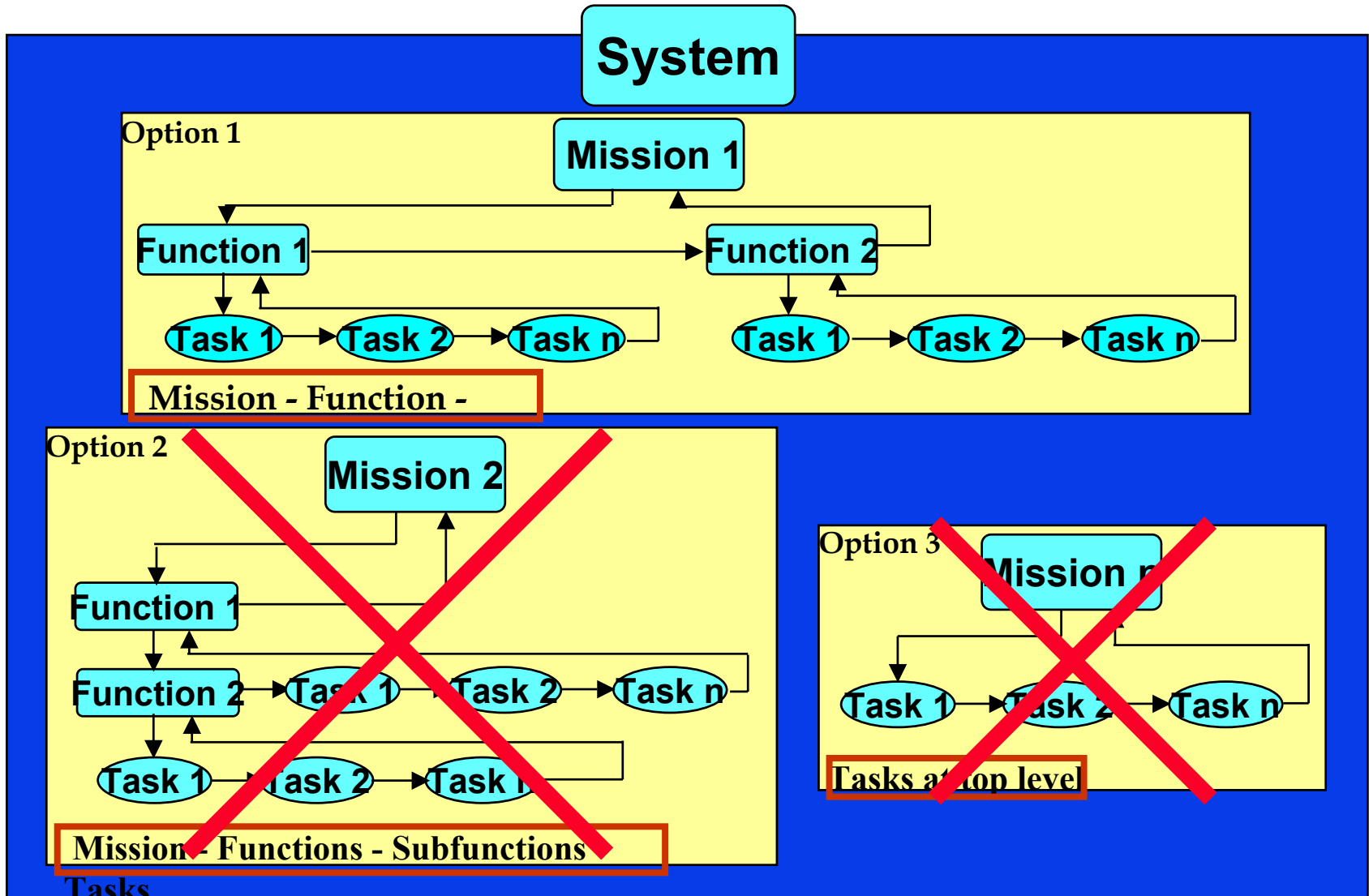
# *Advanced Modeling*



# *Advanced Modeling vs. Advanced workload*

- ◆ Advanced modeling capabilities allow you greater flexibility in controlling the sequence of events in your model
  - Effects tab
- ◆ Advanced workload is another model for predicting workload based on multiple resource theory

# Task Network Hierarchy Options in Advanced





# Multiple Resources Theory of Mental Workload

**Mission  
Tasks**



**Which Brain  
Resources  
Involved?**



**Degree of  
Resource Use?**

1. monitor  
alarms

2. decide  
response  
action

3. pull trigger

•  
•  
•

n. task n

**Visual**

**Cognitive**

**Auditory**

**Motor**

**Speech**



**Speech**

**Visual**

**Auditory**

**Motor**

**Cognitive**

- 0.0 No Cognitive Activity
- 1.0 Automatic (simple association)
- 1.2 Alternative Selection
- 3.7 Sign/Signal Recognition
- 4.6 Evaluation/Judgment (consider single aspect)
- 5.3 Encoding/Decoding, Recall
- 6.8 Evaluation/Judgment (consider several aspects)
- 7.0 Estimation, Calculation, Conversion

## ADVANCED WORKLOAD CALCULATION:

$$W_T = W_{STD} + (W_{WCC} + W_{BCC})$$

**Where:**

$W_T$  = Instantaneous Workload at Time T

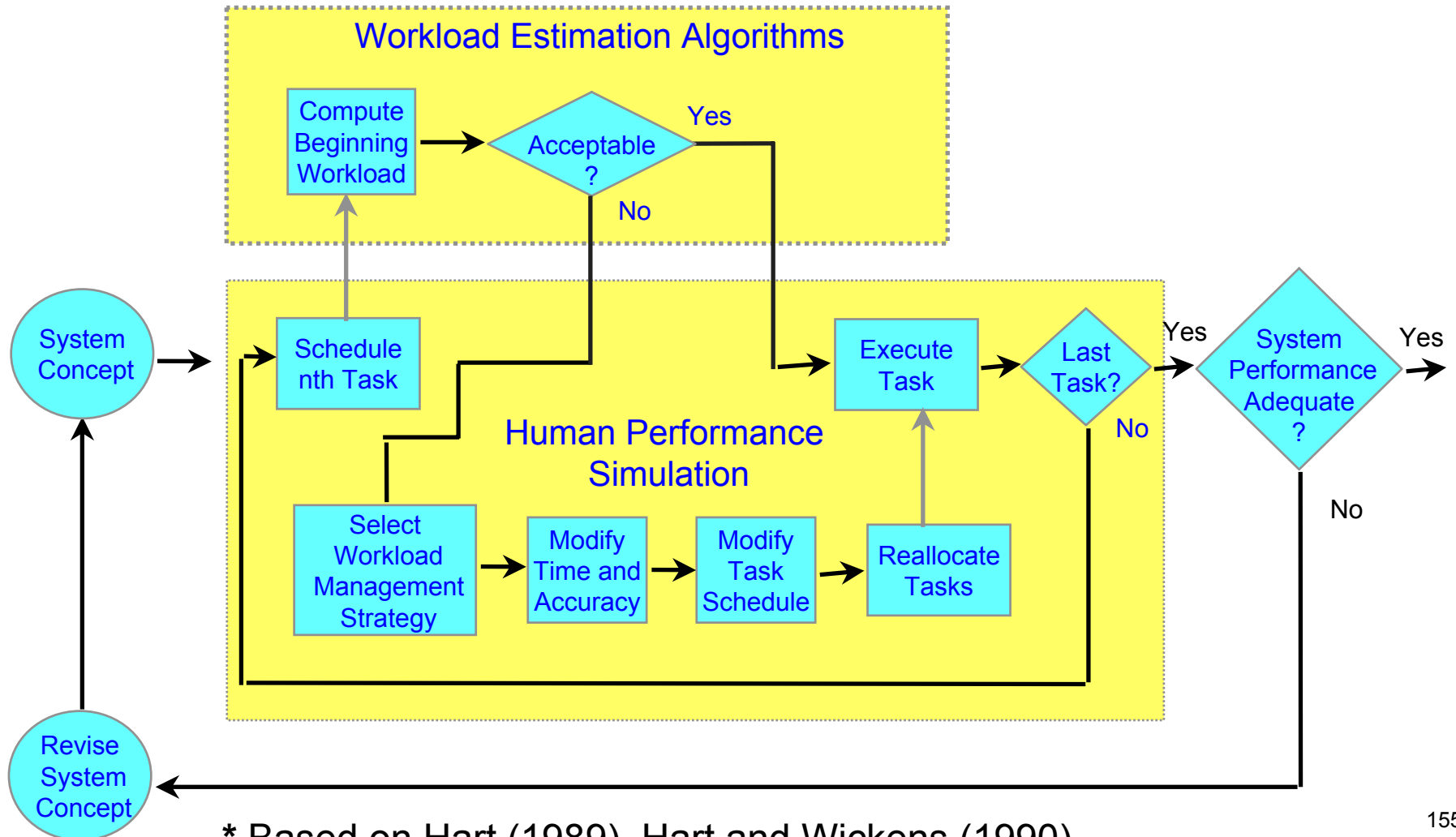
$W_{STD}$  = Workload attributable to the demands of all operator's tasks at time T (Single Task Demands)

$W_{WCC}$  = Workload attributable to Within-Channel Conflicts (Within and between tasks)

$W_{BCC}$  = Workload attributable to Between-Channel Conflicts (Between tasks only; within tasks may see improved performance "S-C-R")

# Advanced Workload Coping Behaviors

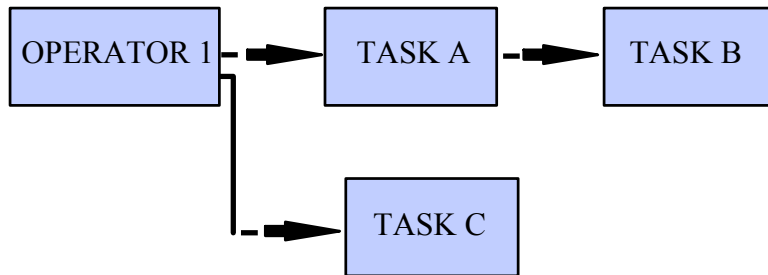
## Interaction of Human Performance and Workload Estimation Algorithms



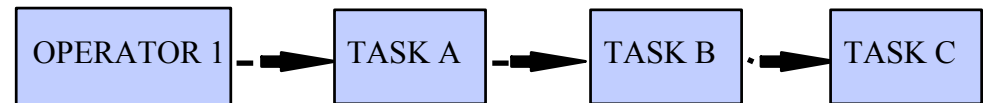
\* Based on Hart (1989), Hart and Wickens (1990)

# Workload Management Strategies Illustration

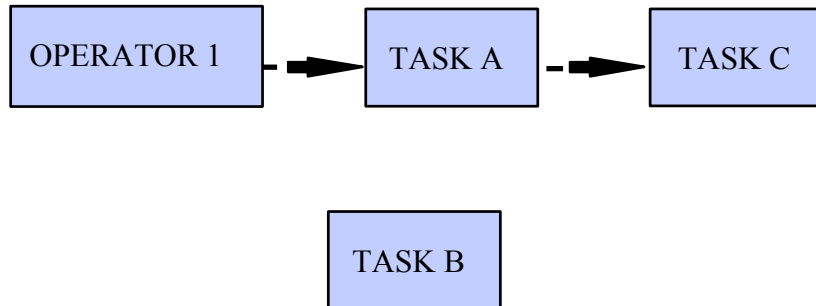
## Strategy - Perform the Tasks Concurrently Despite Overload



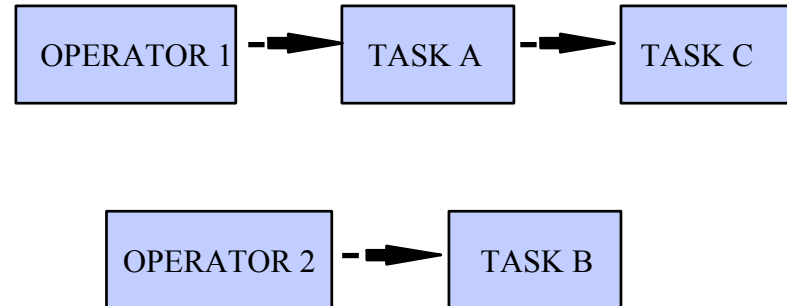
## Strategy - Perform the Tasks in Series Rather than in Parallel



## Strategy - Drop one of the Tasks

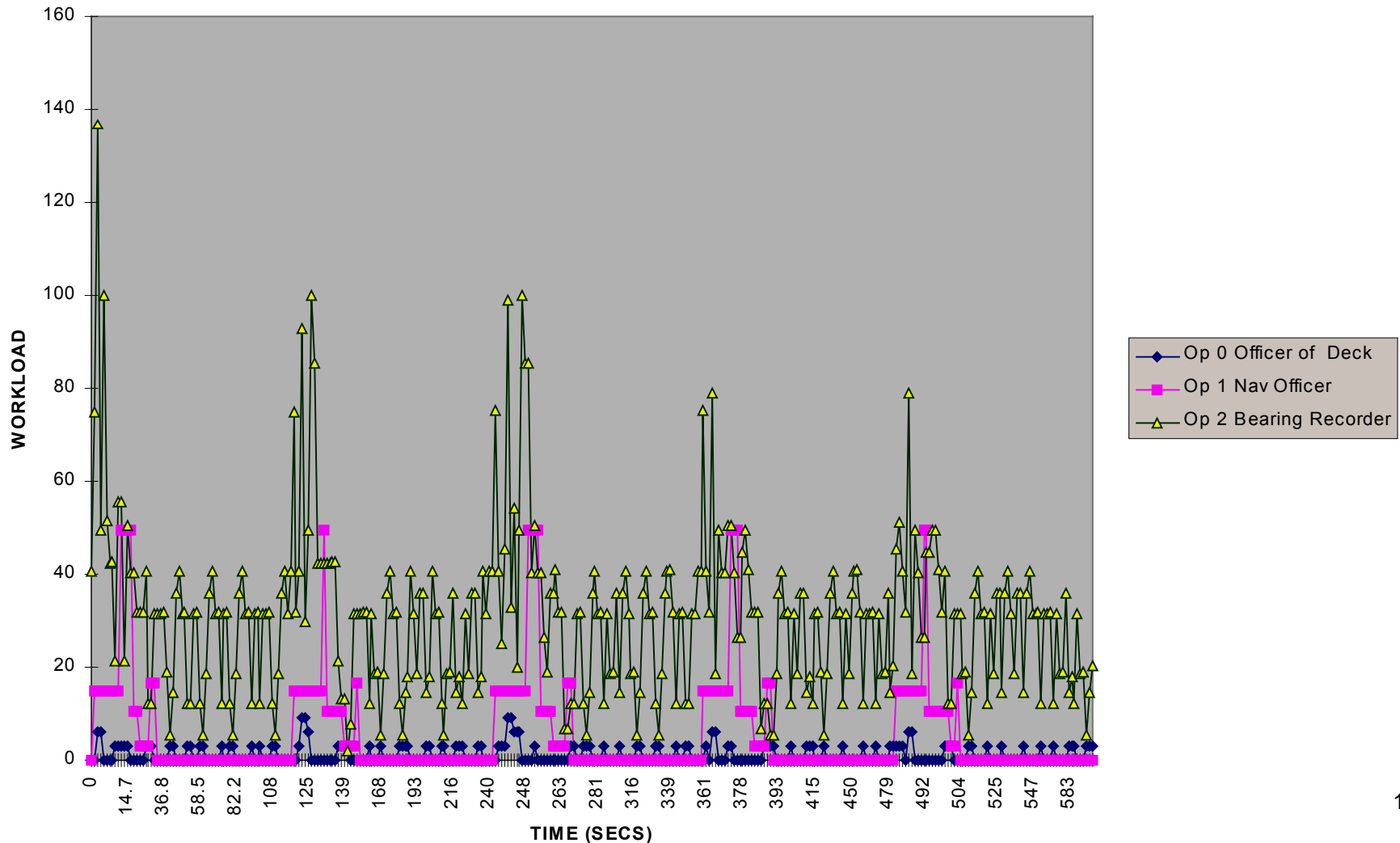


## Strategy - Reallocate Tasks to Another Qualified Operator



# Sample WinCrew Output

**REDUCED, POOR AUTOMATION, GOOD ALLOCATION**



# *Advanced Workload Method*

- ◆ Describes effort needed to perform task
- ◆ To help examine impact of workload during mission
- ◆ Results are combined across channels into one score
- ◆ Results consider inter- & intra-channel conflict
- ◆ Does dynamically impact performance

**Time, Accuracy, Crew Allocation, Sequence**

# *Unique Outputs of Advanced Workload*

- ◆ Critical Path
- ◆ Operator Activity
- ◆ Operator Workload
- ◆ Overload
- ◆ Channel Conflict
- ◆ Task Timeline
- ◆ CrewStation Workload
- ◆ User Snapshot



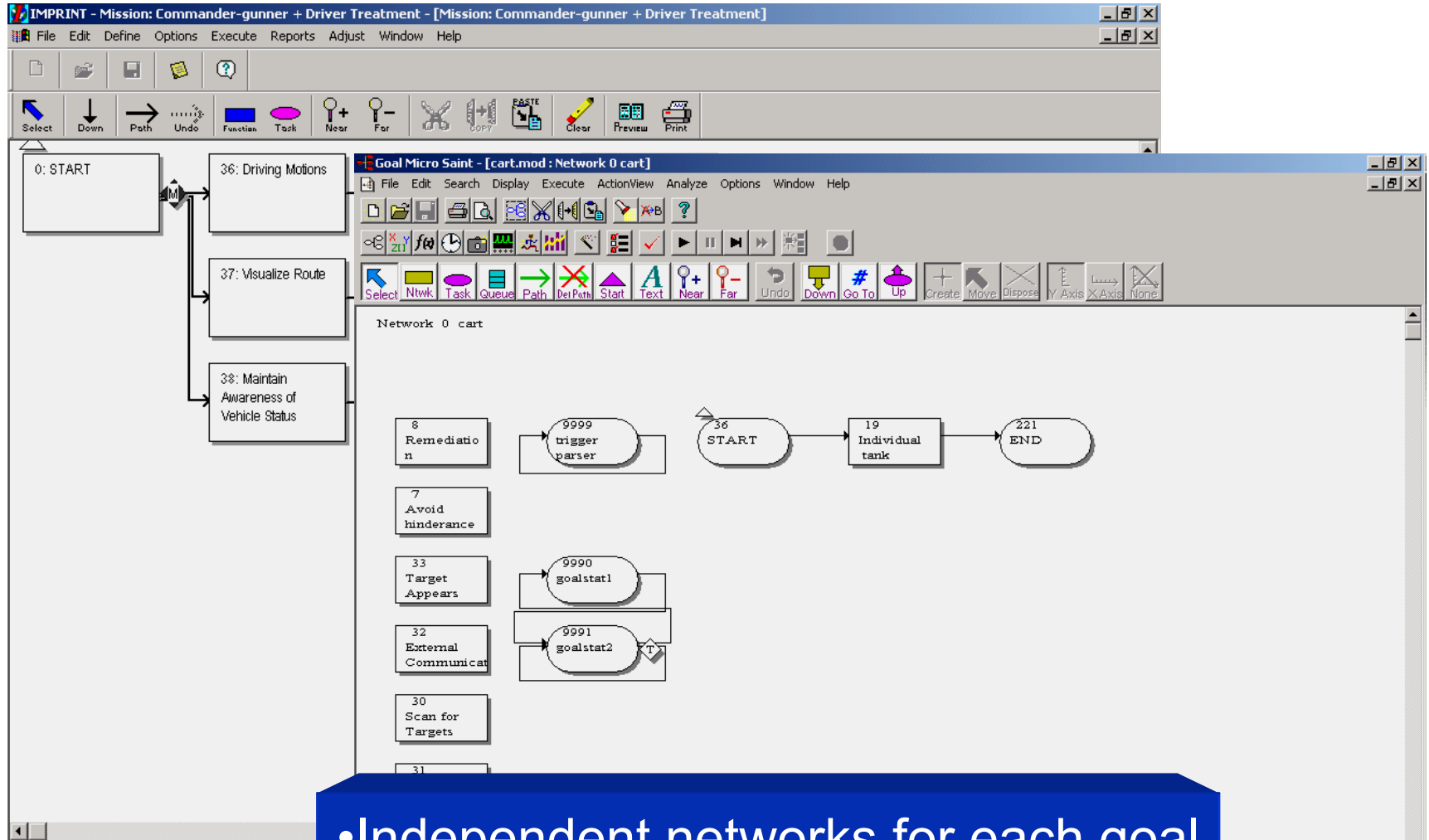
# *Goal Oriented Modeling*



# *Goal Oriented Modeling*

- ◆ Goal orientation
  - Option from VACP
  - Beginning & Ending Effects
  - Variable Catalog
  - Macros (User-Defined Functions)
  - Snapshots
- ◆ COM capabilities
  - Including HLA Middleware
- ◆ Access to tag

# Task Network Model Development



- Independent networks for each goal
- Variables are still global

- ◆ Trigger identification
- ◆ Trigger communication
- ◆ Task interruption
- ◆ Task restart vs. task resume

IMPRINT v7.13a - Analysis: BLOS Version: Aug 02 Mission: Commander-gunner + Driver Treatment

File Edit Define Options Execute Reports Adjust Window Help

Goal Management

Mission: Commander-gunner + Driver Treatment

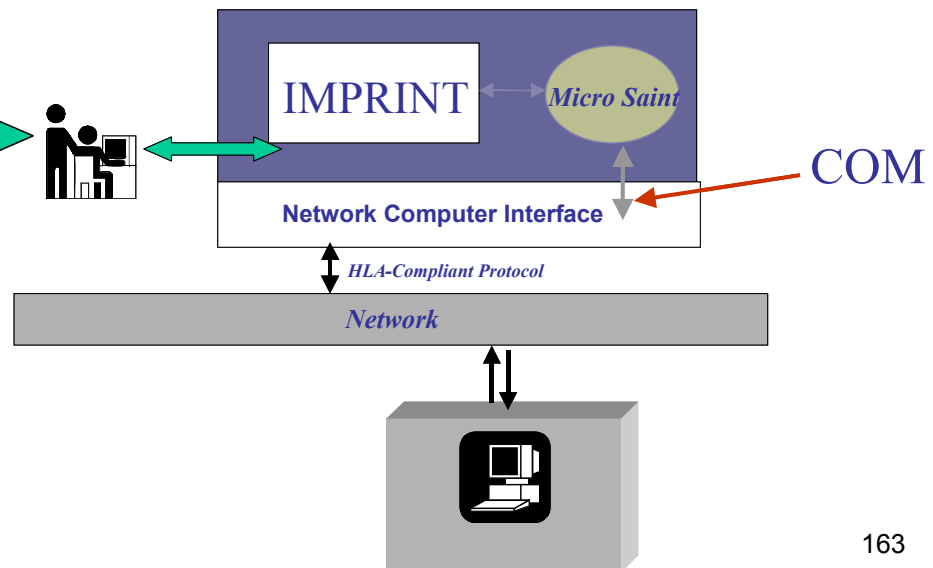
Priority	Initiating Condition	Goal
1	Remediation==1;	Remediation Necessary
2	Hinderance==1;	Avoid hinderance
3	Tgtappear==1;	Target Appears
4	Extcommo==1;	External Communication
5	Targetscan==1;	Scan for Targets

Goal Actions

Mission: Commander-gunner + Driver Treatment

Goal	Mission Running	Remediation Necess	Avoid hinderance	Target Appears R	External Commu	Scan for
Remediation Necessary	Interrupt		Nothing	Nothing	Nothing	Nothing
Avoid hinderance	Interrupt			Nothing	Nothing	Nothing
Target Appears	Nothing				Nothing	Nothing
External Communication	Nothing					Nothing
Scan for Targets	Nothing					Nothing
Perform Crew Communi	Nothing					

Ok Cancel Help





**Goal Management**


Mission:


Priority	Initiating Condition	Goal
1	Remediation==1;	Remediation Necessary
2	Hinderance==1;	Avoid hinderance
3	Tgtappear==1;	Target Appears
4	Extcommo==1;	
5	Targetscan==1;	
6	Crewcommo==1;	


Triggering conditions  
(from internal and  
external simulations)


 Goal Diagram


 Goal Actions


 Variable Catalog

 Add Goal

 Cut Goal

 Ok

 Cancel

 Help

Description of Selected Goal:

**Goal Actions**

Mission:

Goal	Mission Running	Remediation Necess	Avoid hinderance	Target Appears R	External Commun	Scan for
Remediation Necessary	Interrupt		Nothing	Nothing	Nothing	Nothing
Avoid hinderance	Interrupt			Nothing	Nothing	Nothing
Target Appears	Nothing				Nothing	Nothing
External Communication	Nothing					Nothing
Scan for Targets	Nothing					
Perform Crew Communic	Nothing					

**Action matrix – to define goal interactions**

Ok  
Cancel  
Help

## ◆ When a trigger comes true:

- Look UP the matrix to see if a higher priority goal would suspend or halt it. If so, don't start it, but keep trying.

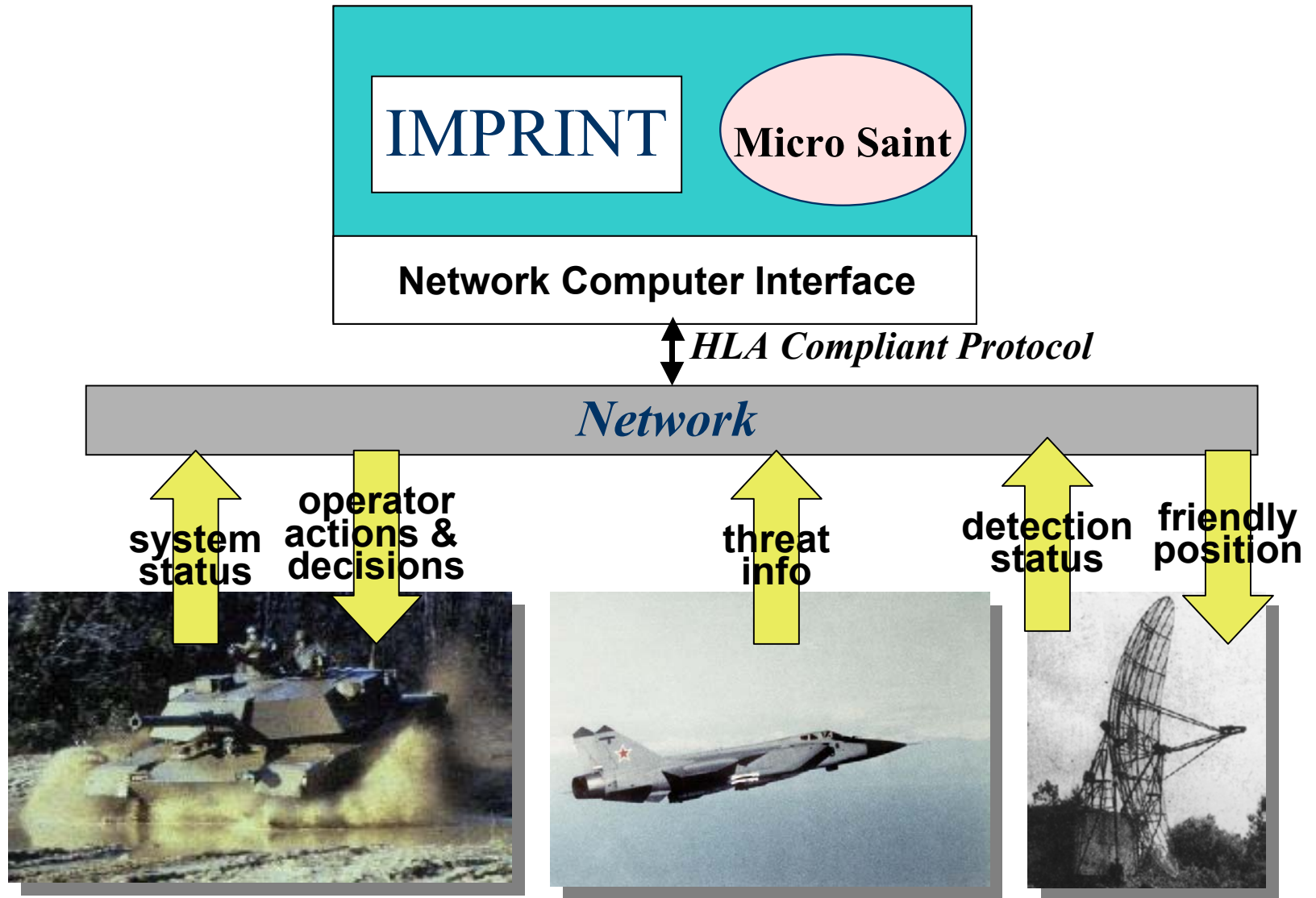
If not:

- Look DOWN the matrix and implement the actions for all lower priority goals

## ◆ When a goal ends normally, gets halted or gets suspended:

- Resume anything it suspended UNLESS a higher priority goal would halt it. If so, halt it. If a higher priority goal would suspend it, then suspend it.

# System Architecture



- ◆ AF Validation Success Story
  - Wright Pat SIMAF Virtual Strike Warfare Environment
  - Time critical targeting (SCUD Hunt) mission
  - HPM vs. Eight pilots (F16 and A10)
  - Overall kills of ground targets in the time critical scenario was virtually the same for both the model and pilots (100% and 98%, respectively)
  - HPM accounted for 61 percent of the behavior of the pilots in the simulation environment
  - New tactic discovered: Coordinated use of synthetic aperture radar (SAR) and targeting infrared (TIR) imaging system





# ***Why would you use Goal-Oriented?***

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- 1. When you want VACP workload and the ability to use effect modeling**
- 2. When you want to represent human behavior using goals**
- 3. When you need to talk to other simulations**

You can switch from VACP or Advanced to Goal oriented with caveats!

# *Wrap-Up Discussion*

- ➡ Save ! Save! Save!
- ➡ Never too many DUMMIES...
- ➡ Naming Conventions

## **Who**

- ◆ Any government agency
- ◆ Private industry with government contract
- ◆ Foreign government (case-by-case)

## **How**

- ◆ Send request via e-mail or letter
- ◆ If private industry include government contract number and organization

## **Non-Distribution Form**

- ◆ Keep track of users
- ◆ Reminder not to distribute

## **Software Distribution**

## **Who**

- ◆ Any government agency
- ◆ Private industry with government contract
- ◆ Foreign government (case-by-case)

## **How**

- ◆ Send request via e-mail or letter
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- ◆ Keep track of users
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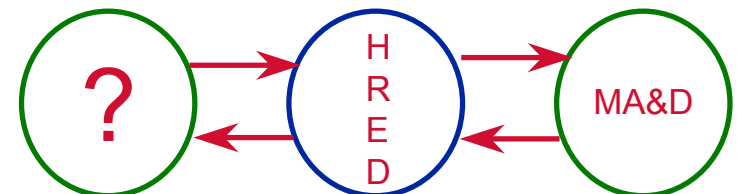
## **Software Distribution**

## ARL-HRED

- ◆ Ms. Celine Richer (cricher@arl.army.mil)  
(410) 278-5883
- ◆ Ms. Diane Mitchell (diane@arl.army.mil)  
(410) 278-5878
- ◆ Ms. Jody Wojciechowski (jqw@arl.army.mil)  
(410) 278-8830
- ◆ Ms. Charneta Samms (csamms@arl.army.mil)  
(410) 278-5877

## Maintain Database

- ◆ User comments
- ◆ “Bugs”
- ◆ “Fixes”





# *Using the List Server*

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List of current IMPRINT users & interested parties

Send suggestions, comments, general information or questions regarding IMPRINT to

[imprint@arl.army.mil](mailto:imprint@arl.army.mil)



# References

- ◆ Allender, L., Kelley, T. D., Salvi, L., Lockett, J., Headley, D. B., Promisel, D., Mitchell, D., Richer, C., and Feng, T. Verification, validation, and accreditation of a soldier-system modeling tool. Proceedings of the Human Factors and Ergonomics Society 39th Annual Meeting-1995, San Diego, pp. 1219-1223.
- ◆ Allender, L., Salvi, L., and Promisel, D. (June 1997). Evaluation of Human Performance under Diverse Conditions via Modeling Technology. Proceedings of Workshop on Emerging Technologies in Human Engineering Testing and Evaluation, NATO Research Study Group 24. Brussels, Belgium.
- ◆ Allender, L., Kelley, T., Archer, S., and Adkins, R., (1997). IMPRINT The Transition and Further Development of a Soldier-System Analysis Tool. MANPRINT Quarterly, Office of the Deputy Chief of Staff of Personnel, Vol. V, No. 1.
- ◆ Dahl, S., Allender, L., and Kelley, T., (1995) Transitioning Software to the Window Environment - Challenges and Innovations. Proceedings of the Human Factors and Ergonomics Society 39th Annual Meeting - 1995, San Diego, pp. 1224-1227.
- ◆ McMahon, R., Spencer, M., and Thornton, A. (1995). A quick response approach to assessing the operation performance of the XM93E1 NBCRS through the use of modeling and validation testing. Presented at the Military Operations Research Society Symposium.
- ◆ Micro Analysis & Design. Stressor Review Report: Enhanced Performance Degradation Factors and Upgrades for Improved Performance Research Integration Tool (IMPRINT) Version 5, Dynamics Research Corporation: 1-54.
- ◆ Mitchell, D. K. (2000). Mental workload and ARL workload modeling tools. (ARL-TN-161) Aberdeen Proving Ground, MD: Army Research Laboratory.
- ◆ Mitchell, D., Samms, C., Henthorn, T., Wojciechowski, J. (2003). Trade Study: A Two-Versus Three-Soldier Crew for the Mounted Combat System (MCS) and Other Future Combat System Platforms. (ARL-TR-3026) Aberdeen Proving Ground, MD: Army Research Laboratory.



*Thanks for Coming!*